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AN ANALYSIS OF LOG PRODUCTION IN THE "INLAND EMPIRE" REGION[1]

By M. BRADNER, *in charge Office of Forest Products, Northern Rocky Mountain Region;* F. J. KLOBUCHER, formerly *Forest Examiner;* J. W. GIRARD, *Logging Engineer, Division of Forest Economics, Branch of Research;* and S. V. FULLAWAY, JR., formerly *in charge Office of Forest Products, Northern Rocky Mountain Region, Forest Service.*[2]

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INTRODUCTION

The importance of logging, or the complete task of handling logs from standing timber to the sawmill or common carrier, is indicated in the enormous annual log output of the Nation. It is estimated that between 35,000,000,000 and 40,000,000,000 board feet of timber is taken out each year in the form of log-sized material. Furthermore, the logging end of the operation in this region actually

[1] The "Inland Empire," which is considered as forming a distinct lumbering region, may be defined for the purposes of this bulletin as including the forested areas in western Montana, Idaho north of the Salmon River, eastern Washington tributary to Spokane, and the northeastern tip of Oregon.

[2] The studies forming the basis of this bulletin were started by Girard in 1919. The collection of the bulk of the field data was made by Girard and Klobucher. Fullaway, while in charge of the office of forest products in the northern Rocky Mountain region, assisted materially in the supervision of the project and in the revision of the original report covering the results of the studies. Bradner prepared the final report for publication, adding to the original work the results of later studies.

The authors wish to acknowledge their indebtedness to all who have aided in any way the accomplishment of this work, particularly to P. Neff, who has helped much in the collection of the data and the checking of results; to Clyde Webb, T. Crossley, R. Williams, R. Ellis, J. E. Keach, A. R. Standiford, R. Woesner, K. A. Klehm, O. A. Knapp, H. Regnes, and I. V. Anderson, now or formerly Forest Service Officers, for the actual collection of field data; and to the Anaconda Copper Mining Co., the Polleys Lumber Co., Beardsmore Lumber Co., Henry Good Logging Co., Whaley Bros. Logging Co., Smith Bros. Logging Co., Baird-Harper Lumber Co., Potlatch Lumber Co., Bonners Ferry Lumber Co., Deer Park Lumber Co., Rose Lake Lumber Co., P. L. Howe Lumber Co., Dalkena Lumber Co., Edwards-Bradford Lumber Co., McGoldrick Lumber Co., and the J. Neils Lumber Co., for the help and cooperation extended in making the studies on their logging operations.

involves about half the total actual cost of production from the stump to the finished product. The best logging methods are accordingly of first importance.

Logging engineering has developed remarkably during the past decade. There has never been, however, a time in the history of the lumber industry when the need for progress in this field was more pronounced than it is to-day. Logging in virgin timber has steadily progressed into the less-accessible and lower-quality stands, and the stumpage value has in general become increasingly higher. The big consuming centers are at great distances from the principal producing regions. Other materials have made substantial inroads upon lumber markets and competition between lumber-producing regions has been greatly intensified by overproduction. Requirements for capital investments and production costs all along the line from stump to finished product are generally increasing. Industrial progress generally, as well as severe competition within the lumbering field, now points to the necessity for the lumber industry to follow the lead of other great industries and place its operations on a sounder basis.

The task of selecting the best method of operation to insure a profit involves more considerations in logging than in most industries. Logging is done under operating conditions which vary constantly. Each individual chance or logging unit, however small, presents a different problem for solution. Further uncertainty is added through the influence exerted by the weather and other natural factors. Owing in part at least to this uncertainty, the successful logger of the past developed considerable resourcefulness. In his decisions, however, he was guided largely by personal experience. The type of improvements, the kind of equipment, the operating methods, and the standard of utilization have quite commonly been adopted upon the personal recommendation of one man. Records of past experience were seldom if ever kept in such form that the information they contained could be applied to other operations.

With the gradual development of logging engineering in recent years, the lumber industry has made marked progress in the use of recorded experience. Personal knowledge and judgment are now qualified and greatly influenced by actual records of past performance and results. Nevertheless, it is still quite widely believed that organization and management in logging are largely matters of personality and personal judgment. There can be no doubt that these factors must continue to be essential in all industry, but in common with all other lines of endeavor, the planning and conducting of logging operations will become less haphazard and uncertain as basic facts are accumulated and come into use and rule-of-thumb methods are displaced by methods that rest more upon recorded facts and less upon personal judgment.

A very material step toward the development of systematic logging methods has been made possible in the "Inland Empire" through a comprehensive investigation of logging output by the Forest Service. Records of actual accomplishment have been obtained for the common methods of operation under a uniform classification of the natural conditions usually encountered. These

records afford a means of accurately and conveniently measuring or estimating performance or productivity. In contrast to the usual cost data, such records have the advantage of permanent value. Being based upon specific conditions, these records are applicable to such conditions wherever found. Thus, these logging-output studies constitute a new and significant departure in the logging-engineering field.

The primary purposes of this bulletin are to present the results of these "Inland Empire" logging-output studies, to analyze the effect of the various factors upon output, to explain their use, and to demonstrate the practical value of such data. Very definite principles and methods are necessarily involved in making logging-output studies. A knowledge of these is essential not only for the proper conduct of such studies but to permit the most intelligent application of them. For this reason a section of the appendix is devoted to a discussion of the principles and methods involved.

Logging-output studies furnish information of permanent value. Such data can be converted readily and accurately to a dollar or cost basis by the application of current wage scales and costs, and form, therefore, a reliable means of estimating the cost of logging. As a result they can be put to practical use in the appraisal of stumpage values, in bringing about better logging methods, in the intelligent letting of contracts, and in determining sound and profitable utilization standards.

Output records, in conjunction with a detailed examination of conditions on the ground, afford the means of determining the most logical plan of operation and the best means of accurately appraising operating costs. A knowledge of these costs, quite as much as of manufacturing costs and selling value, is essential to the establishment of a proper stumpage value. Output records also enable the operator to make a true comparison of the actual merits of the different kinds of improvements, equipment, and methods for each logging chance, and thus assure the most efficient and economical operation. They make it possible to check the output of men or machines with the normal output, so that contracts to meet specific conditions may be let upon an intelligent basis.

The profitable cutting size and limit of defect in a stand of timber can be determined only from detailed and accurate data such as are obtainable in logging-output and milling studies. Through the application of such cutting limits not only is a more profitable operation possible, but the selection cutting resulting therefrom usually leaves the area in a more productive state. This is the first step in good forestry practice.

SCOPE AND NATURE OF THE OUTPUT STUDIES

The studies of logging output made in the "Inland Empire" region by the Forest Service from 1919 to 1928, inclusive, have covered all of the several important timber-type classifications of this region for both the winter and summer logging seasons. The bulk of the field data forming the basis for this report was collected during the first five years of this period. These data are supplemented by further logging-output studies conducted since 1923. A

number of studies covering all phases of tractor logging from stump to landing in the ponderosa pine type were made in 1928. The volume of timber handled in the various branches of the logging operation covered by all of those time and output studies is as follows:

	M. ft. b. m.		M. ft. b. m.
Sawing	3,206	Dray hauling	840
Horse skidding	7,483	Sleigh hauling	2,146
Tractor skidding	4,663	Autotruck hauling	1,441
Donkey skidding	773	Trailing in chutes	1,917
Loading sleigh	222		
Loading autotrucks	765	Total	23,456

Studies have been limited to sawing, skidding, trailing in chutes, loading on sleighs and autotrucks, hauling, and slash disposal. All of these steps in the logging operation come between the stump and the landing—where a large share of the log cost usually occurs and furthermore where errors of judgment are most likely to prove very expensive. Moreover, the factors which appreciably affect the output in these phases of the logging operation are readily distinguished and classified both at the time of study and in the subsequent application of the data.

Operation in some branches of the work, such as railroad and flume transportation, is so well standardized that data of sufficient accuracy are available from cost accounts. Moreover, in these branches output depends largely upon independent influences such as demand for logs and the output in other branches of the operation. The same is true of " tailing down " on landings and decking logs. Output studies in these branches have therefore been excluded.

No attempt was made to give any indication of the relative efficiency of individual workmen, units of organization, or equipment. This was not the object in view. Once an average representing the output of a number of units crews is made available, however, it becomes a good yardstick with which to measure the work of other men or machines on similar jobs. The variation due to the human element in individual crews has not been studied. So far as possible this influence has been eliminated by securing records for a large number of men or crews selected at random.

In every other respect as well, the aim in these studies has been to obtain information which would be of general use in the region, represent average results obtainable, apply to specific conditions, and be as nearly permanent as possible.

In the woods, output data were collected only from crews of standard size. Only those men whose work directly affected the output of the unit organization were considered as part of the crew. The work of a large number of unit crews or machines, irrespective of their relative efficiency, was followed.

The output data were collected under definite classifications as to the natural conditions found on the different areas. Of these conditions the species or forest type, size of timber, slope, and season of the year exert the greatest influence upon logging output and therefore were adopted as the primary classification elements. Height of trees, stand per acre, windfall and undergrowth, and surface, although recognized in the collection of data as affecting output in varying degrees, were considered of minor importance.

Distance, gross volume, and time were the basic units of measurement used. Distance, when a factor in output (as in skidding with horses), was always taken as the actual distance along the slope under load and not the horizontal distance. Gross scale by the Scribner decimal C log rule was used as the unit volume of measurement for all branches of logging, since, if net scale had been used, the data would have been applicable only to stands containing the same percentage of defect. Where it is desired to determine output or cost for any particular stand of timber, the estimated percentage of defect in that stand may be applied to the gross scale.

Only actual working time plus any normal lost time is included in job measurements. For example such time is excluded as that lost by a skidding team because of a filled skidway, or that chargeable to any other branch of logging work but skidding itself. Actual working time includes such time as is lost in resting, minor repairs of equipment, or overcoming any other difficulties encountered in actually doing the work—such as hanging up a tree in sawing. Where teams were doubled up to skid a large log, the trip time was doubled.

The hour was adopted as the standard unit for measuring the labor used on the job. The use of the effective hour as a unit, in contrast to the day or dollar, avoids the complexities which otherwise result from constant fluctuations in wages and the length of the working day as, for instance, where travel from camp to the job is on company time and must be deducted from the standard day before effective hours can be arrived at. In using the output data as here presented it is necessary only to apply the output per hour to the estimated number of effective hours which it is possible to put in on the job.

The refinement justified in time and output studies of any kind of work is dependent largely upon the variations found in the working conditions. It is of no practical value to determine the individual effect on output of factors which can not be controlled. The degree of detail necessary to make certain that the data on any particular unit crew or piece of equipment represent the average performance depends upon how consistent the crews are in their work, the nature of the conditions under which the work is done, and the range over which the figures must be distributed. More data are necessary when the logs are skidded on the ground by horses than when trailed in chutes, since the improvements in the latter case have more nearly standardized working conditions. Undoubtedly the greatest variations occur in work into which the human element enters to the greatest degree. A full discussion of the refinement justified and the amount of information necessary to assure average data in these studies is given in the appendix.

LOGGING-OUTPUT GRAPHS AND THEIR USE

The actual output data for the different branches of logging are presented in the form of graphs for all activities except swamping and slash disposal; these are given in tabular form. The studies include the following steps in the operation in the order in which they are presented: Sawing (including felling and bucking in the woods, felling, limbing and topping, and bucking on the landing);

skidding (horse, tractor, donkey engine, and big wheel); loading and unloading; transportation other than skidding (including trailing in chutes and hauling on drays, sleighs, and autotrucks); and swamping and slash disposal.

A discussion of the factors affecting output, together with facts pertinent to the understanding and specific use of the graphs, accompanies each set of data. In order to facilitate the use of the graphs in determining operating costs, a number of examples or problems and their solution are given for each branch of logging studied. Output or cost can be determined to a finer degree than that indicated here by interpolation between the values shown. Even where existing methods and conditions do not fall within the range of the data presented, the information here given will often be of value as a general guide to, or an indication of, what might be accomplished.

Certain very definite principles or basic facts about logging must be fully understood before output data of the type presented can be used effectively. The influence of defect in timber is reflected as a uniform flat reduction in the quantity of output in all ends of the logging work. There is no appreciable difference in output between defective and sound material on the basis of gross-scale volume. The amount of work involved in handling two logs of similar size, one sound and the other one-half defective, is practically the same. The actual net output in the case of the defective log would, therefore, be one-half that of the sound log.

Breakage reduces sawing output but increases that of all other parts of the operation from stump to mill pond, since the greatest percentage of breakage occurs in the small-top logs. The elimination of these from the run increases the average size of the log cut from the stand.

The size factor which determines output in all branches of the operation except sawing is the scale of the log rather than the dimensions from which that scale is derived. If two logs, one 20 feet and the other 12 feet in length, each scale 140 feet, practically the same output will be obtained from both. On the standard 16-foot length basis, however, one would run 9 logs and the other 5½ logs per thousand feet board measure. Therefore, by cutting a stand of timber which averages 10 logs per thousand into logs 24 feet long, an output would be obtained approximately the same as that from a stand running seven 16-foot logs per thousand. This same ratio will not hold in sawing. Cutting 10-log material into 24-foot lengths gives an output far above that for 7-log material cut into 16-foot lengths.

Overrun is in reality a makeshift used to arrive at actual lumber contents when the scale rule fails to record actual contents, as it does most signally in the measurement of small logs. It will be used in connection with an attempt to determine the marginal log material which can be profitably handled.

An accurate timber estimate and a topographic or drainage map are essential to the most effective application of the data shown in the graphs in evaluating stumpage or determining the best methods of operation for a particular logging chance. Thus, after a careful examination of the area, the logging engineer with these aids, has all the facilities necessary to arrive at very definite conclusions as to

the best methods and the cost of these methods. This presumes, of course, that the appraiser has experience, judgment, and initiative, and is willing to put the data to their best use.

ANALYSIS OF SAWING-OUTPUT DATA

The output data for sawing are presented graphically in Figures 1 to 13, which are summarized in Table 1. The output per effective hour gross scale is based upon the work of two men and is determined both by diameter breast high groups and number of logs per thousand board feet of timber cut. A 2-man saw crew is the standard crew for either day or contract work. All output curves are, unless otherwise designated, applicable to jobs where the average log is approximately 16 feet in length. This is the approximate average length of all short logs cut in this region.

EFFECT OF NATURAL FACTORS ON SAWING OUTPUT

Natural factors which affect the sawing output, considered in the approximate order of their importance, are size of timber, species of timber,[3] season of the year, defect in timber, and slope, windfall, and undergrowth.

Sawing output up to certain sizes is influenced to a greater degree by the diameter of the timber than by any of the other natural factors affecting it. This influence is evident in every set of data where output is given according to size. In general, there is a fairly rapid increase in the output per saw crew per hour for each 2-inch diameter increase in the size of the trees cut, from the smallest trees on which data were obtained up to those 30 to 40 inches in diameter breast high.[4] Somewhere within these diameter limits, depending on the species cut, a point is reached where for several diameter sizes the output of the crew does not increase as the size of the timber increases. From this point on, as still larger trees are cut, the output per hour gradually falls off. This does not follow, however, with logs of unusual length. (Fig. 13.)

The curve in Figure 1 shows the output per crew (working on a day basis) per hour for western white pine to be 470 board feet for 12-inch trees (diameter breast high), 940 board feet for 20-inch trees, and 1,210 board feet for 28-inch trees. The maximum output per crew per hour under the condition as described on the graph (1,270 feet board measure) was reached in sawing trees 34 to 36 inches diameter breast high. Logs from western white pine trees of these sizes would run from three and one-half to three logs per thousand. From this point on, the output of the saw crew decreased as the size of the trees cut increased. The curve shows an output per saw crew per hour of 1,200 board feet for the 44-inch tree, the largest diameter group for which data were obtained. Practically the same output

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[3] The commercially important tree species referred to in this bulletin are:

Botanical name	Accepted common name	Trade name
Pinus monticola D. Don	Western white pine	Idaho white pine.
Pinus ponderosa Laws	Ponderosa pine	Ponderosa pine.
Larix occidentalis Nutt	Western larch	Larch.
Pseudotsuga taxifolia (LaM.) Britt	Douglas fir	Douglas fir.
Picea engelmannii Engelm	Engelmann spruce	Spruce.
Abies grandis Lindl	Lowland white fir	White fir.
Tsuga heterophylla (Raf.) Sarg	Western hemlock	Hemlock.
Thuja plicata D. Don	Western red cedar	Cedar.

[4] D. b. h.=diameter, breast high, or 4½ feet above ground, measured outside (including) bark.

TABLE 1.—*Index to sawing graphs*

Fig. No.	Forest type	Slope	Species	Stand per acre	Season	Surface conditions: Brush	Surface conditions: Windfall	Surface conditions: Surface	Surface conditions: Snow depth	Method	Labor
		Per cent		*M.ft.b.m.*					*Inches*		
1	Western white pine	0-30	Western white pine	10-20	Winter	Medium	Medium	Smooth	20	Felling and bucking	Day.
2	do	30-50	Western white pine and white fir, larch, Douglas fir, cedar.	25	do	Light to medium	Light	do	0-40	do	Contract.
3	do	30-50	Western white pine type.	25	do	do	do	do	12-15	do	Three contract crews.
4	Ponderosa pine	0-30	Ponderosa pine	8-12	Summer	Light	do	do		do	Day and contract.
5	do	0-30	Douglas fir	10-12	do	do	do	do		do	Contract.
6	Larch, Douglas fir	0-30	Larch		Winter	Light to medium	do	do	18	do	Day.
7	Ponderosa pine	0-30	do	10-12	Summer	Light	do	do		do	Contract.
8	Engelmann spruce	0-15	Engelmann spruce and balsam fir.		do	Medium	do	do		do	Do.
9	Western white pine		Western white pine and white fir.		Winter					Bucking or landing	Do.
10	do	15-50	Western white pine and white fir, larch, and Douglas fir.	15	do	Medium	Medium	Smooth	30-40	Felling and topping	Do.
11	Ponderosa pine	15-50	Ponderosa pine	10	Summer	do	Light	do		do	Do.
12	do		do		do					Bucking on landing	Do.
13	do	20-45	do	10	do	Light	Light	Smooth		Felling, limbing, and bucking into long logs.	Do.

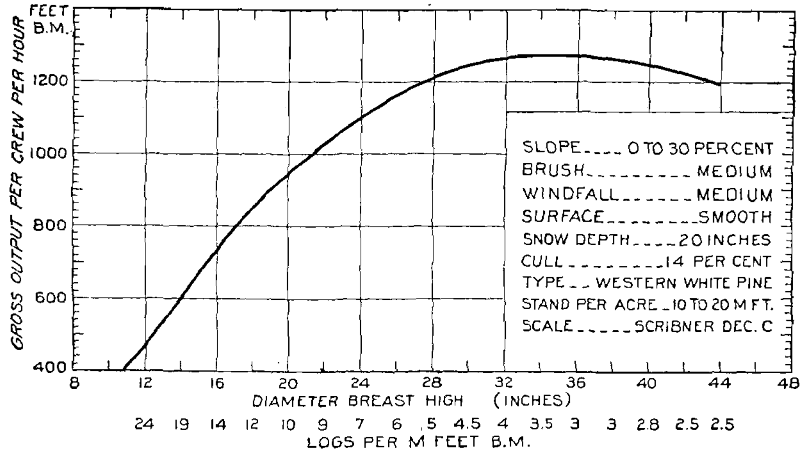

FIGURE 1.—Sawing output (felling and bucking) in western white pine; day labor. Basis, 262 M feet, 205 trees. Data collected December, 1919, and January, 1920

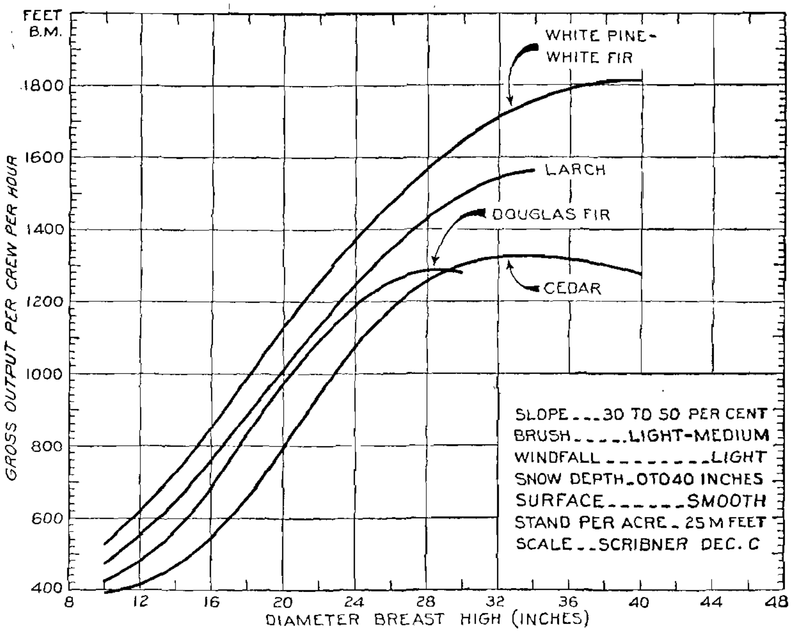

FIGURE 2.—Sawing output (felling and bucking) in western white pine; contract labor. Basis, western white pine and white fir, 600 M feet, 643 trees; larch, 95 M feet, 167 trees; Douglas fir, 48 M feet, 88 trees; western red cedar, 84 M feet, 117 trees. Data collected December and January, 1921

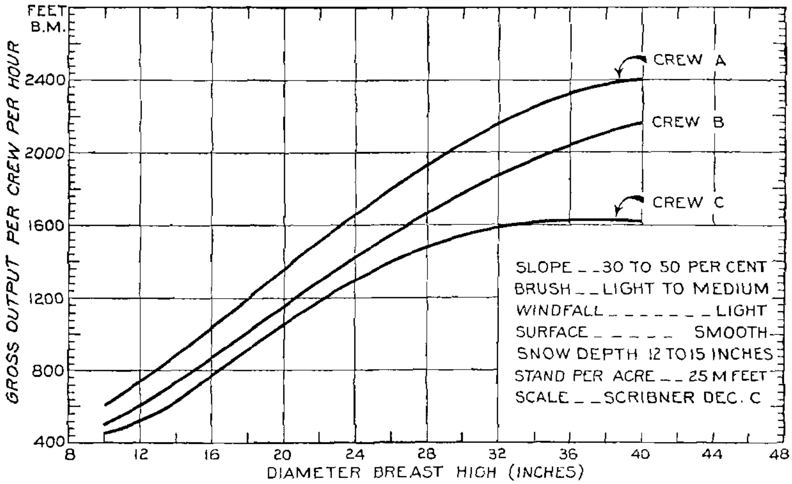

FIGURE 3.—Comparative sawing output (felling and bucking) in western white pine type, under the same conditions, of three different contract saw crews, paid on thousand-feet basis. Data collected December and January, 1921

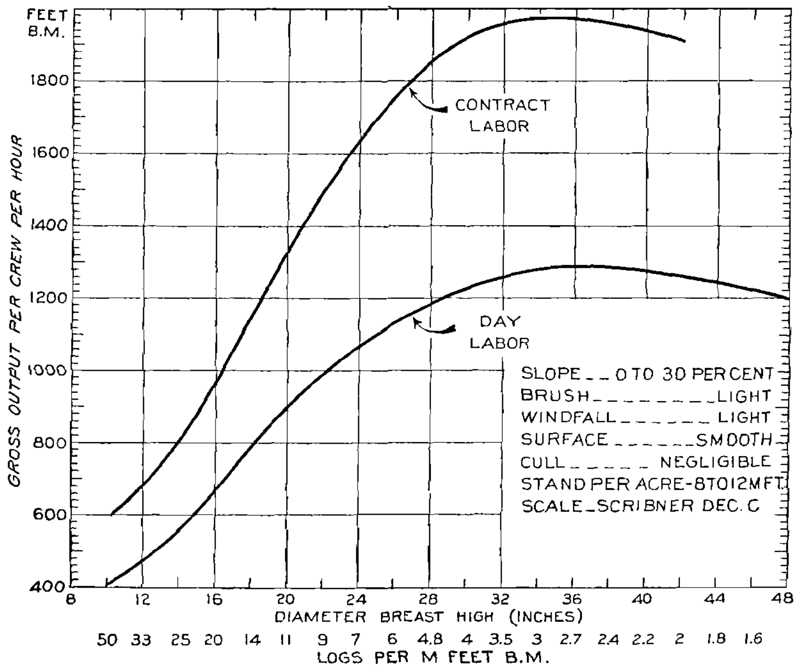

FIGURE 4.—Comparison of sawing output (felling and bucking) in ponderosa pine under day and contract basis. Basis, day work, 413 M feet, 500 trees; contract work, 171 M feet, 204 trees. Data collected summers, 1919 and 1920

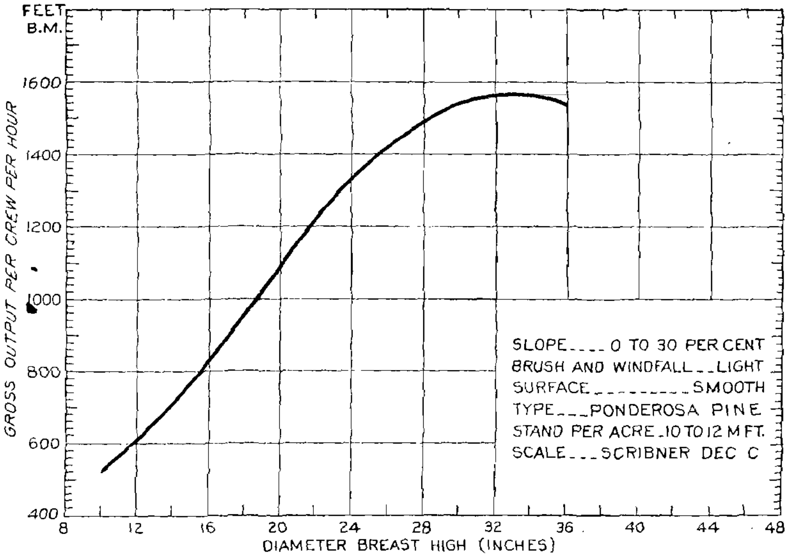

FIGURE 5.—Sawing output (felling and bucking) in Douglas fir, contract labor. Basis, 51 M feet, 203 trees. Data collected summers, 1919–1920

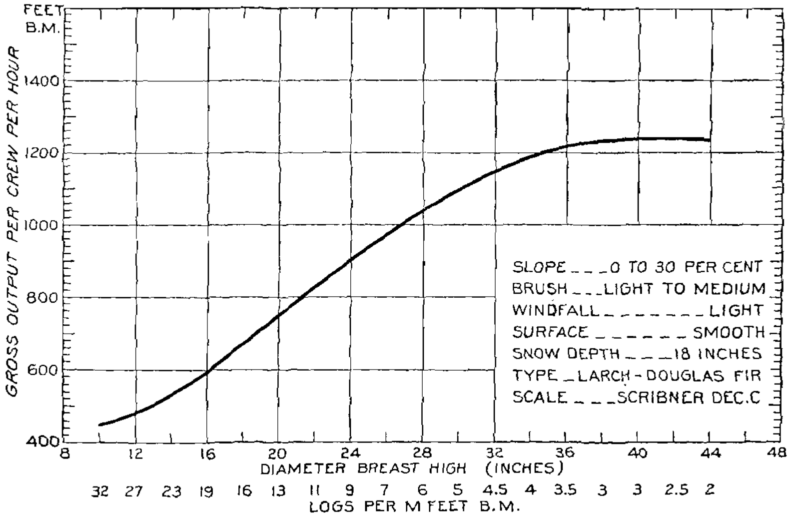

FIGURE 6.—Sawing output (felling and bucking) in western larch, day labor. Basis, 49€ trees. Data collected January and February, 1921

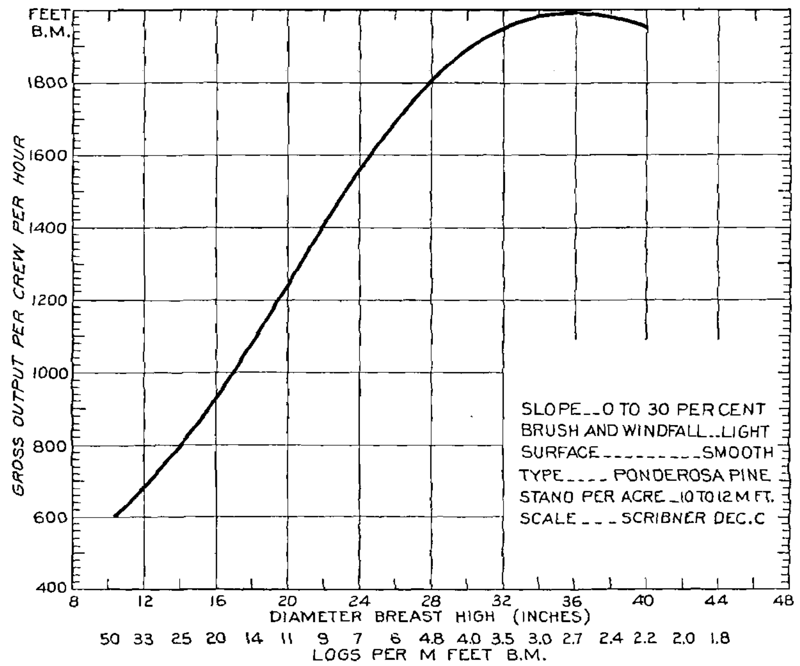

Figure 7.—Sawing output (felling and bucking) in western larch, contract labor. Basis, 87 M feet, 141 trees. Data collected summer, 1920

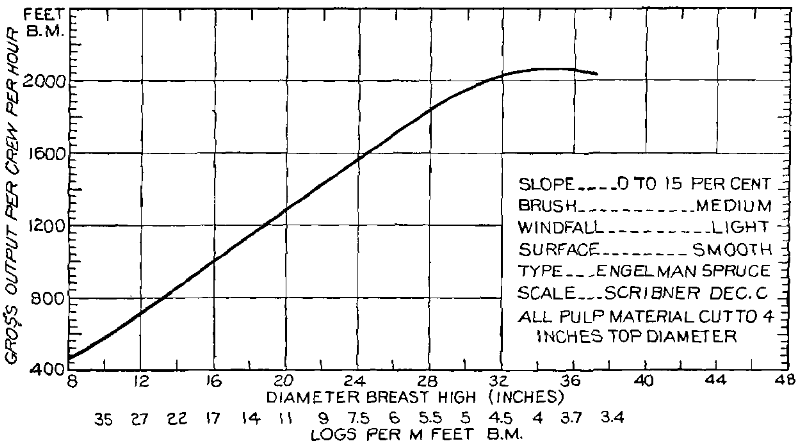

Figure 8.—Sawing output (felling and bucking) in Engelmann spruce and balsam fir, contract labor. Basis, 147 M feet, 478 trees. Data collected August, 1922

was obtained by the crew when sawing 28-inch trees. The day-work sawing curve in Figure 4 shows that in ponderosa pine the maximum output per saw crew per hour was obtained when trees 36 to 38 inches diameter breast high were felled and bucked into logs. In Douglas

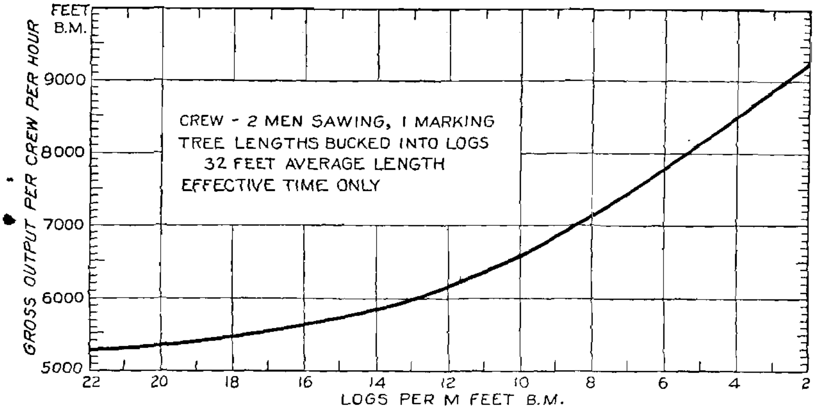

FIGURE 9.—Sawing output (bucking on landing for donkey skidding) in western white pine and white fir, contract labor. Basis, 125 M feet. Data collected January–February, 1921

fir the maximum output of the saw crew per hour (fig. 5) was reached in cutting 32-inch trees; in western larch (fig. 7) in 36-inch trees.

The relatively low output of a saw crew operating in small timber is in great part due to the extra number of trees which must be felled and bucked in order to obtain a scale equal to that resulting where

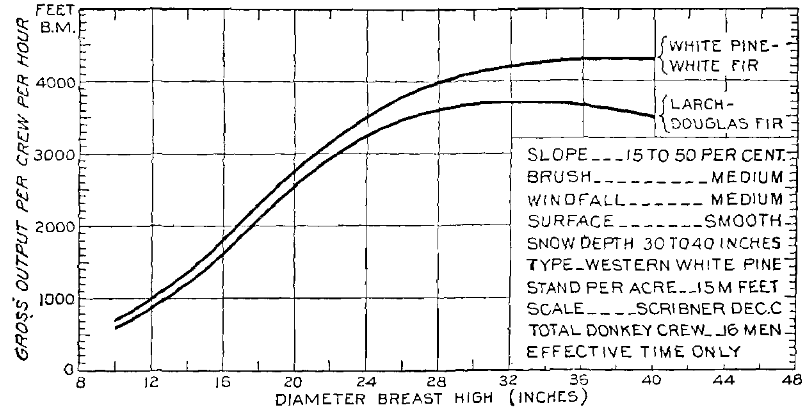

FIGURE 10.—Sawing output (felling and topping for donkey skidding), contract labor. Effective time was 60 per cent of total, lost time being due to felling but one load in advance of skidding to changing line, etc. Basis, 300 M feet. Data collected January–February, 1921

larger trees are cut. Sawyers cutting western white pine trees which average 14 inches diameter breast high and run four and one-half logs to the tree would have to fall and buck four such trees to obtain an output of approximately 1,000 board feet gross log scale. Approximately the same could be obtained by felling and bucking one 25-inch

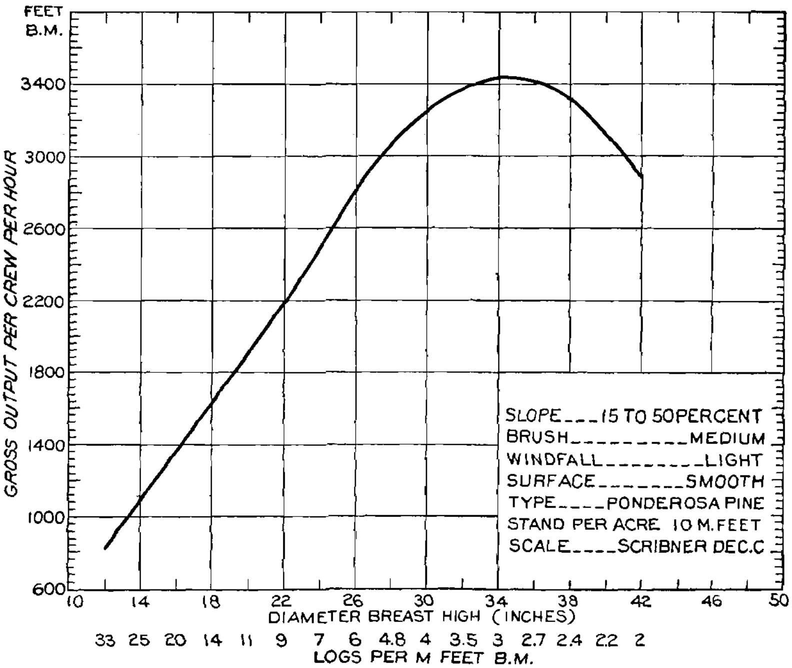

FIGURE 11.—Sawing output (felling and topping for tractor skidding) in ponderosa pine, contract labor. Basis, 263 M feet. Data collected August-September, 1928

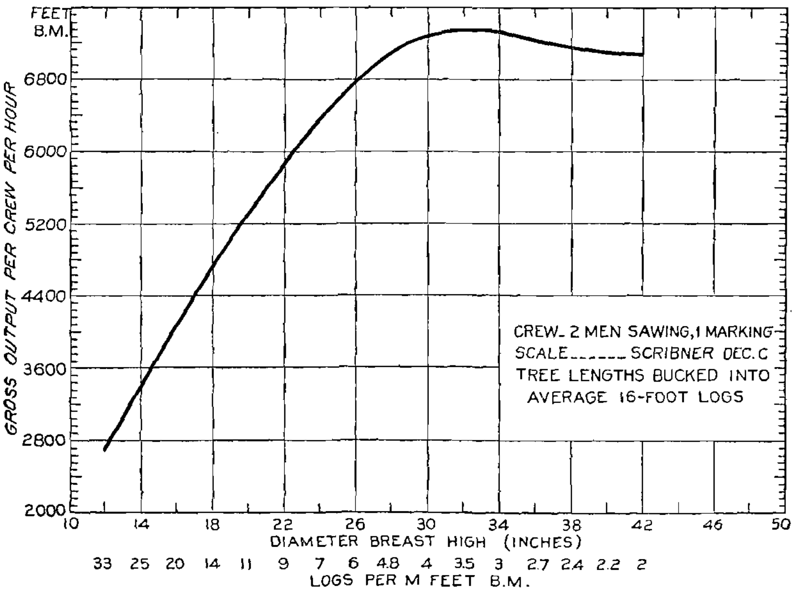

FIGURE 12.—Sawing output (bucking on landing for tractor skidding) in ponderosa pine, contract labor. Basis, 128 M feet. Data collected August, 1928

7-log tree. A large percentage of the total time consumed in the sawing operation is spent in going from tree to tree, brushing out around the tree,and sizing it up, and in the actual felling. Some effective time is lost in the short rest period which often follows the completion of the felling and bucking-up of each tree. The time thus lost is much less per thousand for large timber than for small timber.

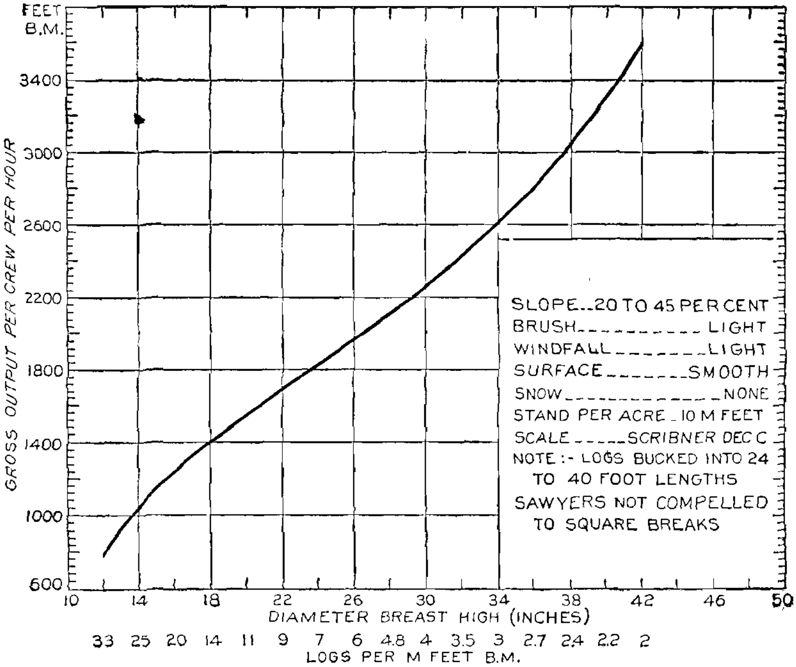

FIGURE 13.—Sawing output (felling, bucking, and limbing three sides for tractor skidding) in ponderosa pine, contract labor. Basis, 182 M feet. Data collected October, 1928

In actual surface to be sawed in felling, the four 14-inch trees would require 1.3 times as much labor as the one 25-inch tree. In the bucking operation, however, although there would be approximately 18 cuts to be made in the 14-inch trees as compared with but 7 in the 25-inch tree, the actual surface to be sawed would be less.

The decrease in output with an increase in size of the trees above 32 to 36 inches diameter breast high (depending on the species) can be attributed in part to three factors—the length of the standard saw used, the additional physical effort necessary to pull the saw, and the increased breakage. The length of the standard saw commonly used in cutting the relatively small-sized timber of the "Inland Empire" is 5½ to 6 feet. This and the 7-foot saw are well adapted to the size of timber normally found. It is possible that a longer saw is needed for more efficient work in timber 36 inches and over in diameter. It has been noted that where exceedingly large cuts are being made the 6-foot saw can be operated to advantage by only one of the sawyers.

Large timber, because of its excessive weight and height, breaks and splits more readily when felled, and the breaks are usually

farther down in the tree than in smaller timber. In bucking the tree into logs, these breaks must be sawed out, and this means from one to several extra cuts of large diameter for the saw crew. Large trees often partly bury themselves in the ground when felled, thus adding to the difficulty of bucking them into logs. There are no other obvious reasons for the decreased output beyond a certain diameter, which is approximately the same for all species.

The species of timber being cut has a considerable influence upon the output that the saw crew will obtain. The hardness and toughness of the wood, the quantity of pitch which it contains, and the character and thickness of the bark are all factors which influence sawing. To these may be added the characteristic shape of the tree butt and bole, and the occurrence and character of the branches. Toughness of wood fiber is another cause of difficulty, requiring that saws be kept in better shape and that more actual power be used to saw through a given thickness. The wood of Rocky Mountain Douglas fir is quite hard and therefore more difficult to saw than that of the pines. The corklike bark of Douglas fir is more difficult to saw through, because of both structure and thickness, than is the relatively thin woody bark of the western white pine or white fir. The stringy, fibrous bark of the western red cedar strips off and clogs the saw teeth. Tree species that are often swell butted, such as western larch and cedar, require a thicker cut in felling than do even-boled trees of the same diameter. Some species of trees clean themselves of branches much more readily than do others, and as a result less swamping is required.

The effect of species characteristics upon the output may be ascertained by a study of Figures 1 to 8. The sawing output per crew per hour in western white pine for 9-log per thousand timber (fig. 1) is 1,025 board feet gross scale. That is 125 board feet more than is obtained by a saw crew cutting in 9-log per thousand western larch. (Fig. 6.) The sawing of both species was done under practically the same conditions, on a day basis during the winter season. The difference in output is no doubt due, to some extent, to the greater thickness of the larch bark and to the characteristic swell butt of this species. In the larger larch trees, long butting is often required; this necessitates an extra cut in bucking.

Figure 2 shows the output per hour for different-sized trees obtained by a contract crew cutting the several associated species in the white pine type. Output per crew per hour for 22-inch trees is 1,250 board feet in western white pine and white fir, 1,135 board feet in western larch, 1,085 board feet in Douglas fir, and 935 board feet in western red cedar. Thus the difference in output between western white pine and western larch obtained by the contract crew is 115 board feet per hour in 9-log per thousand timber, about the same difference as was shown in the output obtained by crews working on a day basis.

The difference in output in summer and winter work, expressed in terms of men and equipment required, is much less noticeable in sawing than in skidding or chuting. Seasonal changes influence sawing in only two respects—freezing of timber and depth of snow, in themselves variables. Frost in timber may be so slight that its effect is not discernable in the output; it may, on the other hand,

be sufficient to cut down output as much as 50 per cent. The same may be said of the depth of snow. It does not hinder the work to an appreciable degree until it reaches a depth which makes its removal necessary in order to get down to the proper stump height in felling. These seasonal changes may take place by imperceptible degrees and will be reflected in output in a similar manner. The average effect of frozen timber and deep snow which may be anticipated in the "Inland Empire" region will not vary appreciably from the average represented by the curves based on winter sawing.

Defect in timber may result in either an increase or decrease in gross-scale sawing output. In certain stages of decay, wood acts as a serious impediment to the cutting speed of a saw, and gross output is materially decreased. This decrease is, however, about offset by the greater speed possible in sawing hollow trees or those containing dry rot, where the work is not obstructed.

Variables which have a minor effect on the output of the saw crew under average conditions in this region are slope, undergrowth, and windfall. Slope above 60 per cent, heavy brush, and windfall would of course greatly decrease the output. A certain degree of slope will add to the ease with which the felling operation may be performed, especially where the cutting of low stumps is required, but this advantage is generally offset by increased difficulties in bucking. After sawing starts, the surface soon becomes littered with felled trees and any interference from the brush and windfall is practically removed. Density of brush and degree of windfall are mentioned in the description of each sawing curve merely as indicative of the character of the stand.

In applying the sawing data to a particular job, the gross-scale output must be reduced by the estimated amount of breakage. Allowance for the probable percentage of breakage should be made during the preliminary examination of the logging chance.

OUTPUT BY DAY AND CONTRACT LABOR COMPARED

In addition to the natural factors which influence the sawing output, an important factor is the basis upon which the saw crew is paid. In this region sawing is done both by day labor and by contract.

It is a well-established fact that a man working on a piece or contract basis will attain a greater output per effective hour than if paid by the day to do the same job. Payment on the basis of the actual work performed is an incentive to greater achievement. Under the contract system, intelligently administered, personal ability, efficiency and hard work are rewarded. During the latter part of the World War and for several years following it, practically all parts of the logging operation were let on a contract basis. Payments were made for the number of thousand feet of logs sawed, skidded, chuted, loaded, or hauled, or at a contract rate per thousand or rod for chutes or roads constructed. The rate per thousand feet board measure or other unit was generally based upon what was considered a fair output per effective unit of time for an average worker or crew working on a day basis.

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The advantages of this system were, however, often lost by faulty application. Accurate records of past performance and results, if available at all, were seldom kept in sufficient detail to permit their use in determining a fair cost for any particular job. The difference in efficiency as between two individual workmen or two unit crews was not always given due consideration. The rate set in many cases was not based upon a fair output for an average crew. In far too many cases improper emphasis was placed upon the net daily earnings of the man or crew, and hard work and personal efficiency were penalized. The lack of accurate information upon which to base the contract rate resulted in considerable bickering and disagreement between the logging operator and his contractors. Lack of confidence in the cost records available or in his own personal judgment often caused the logging operator to change the contract rate a number of times when letting new contracts before the entire job has been completed. For a time contract logging fell into disrepute, and a number of logging outfits returned to the old method of operating on a day basis of pay. In late years there has been a gradual return to the contract method, especially in those branches of the logging operation where the factors effecting output are limited in number and their influence can be determined with comparative ease

Approximately 90 per cent of the sawing in this region is now being done on a contract basis, and payments are made either by the log or per thousand feet log scale. The output curves on all sawing graphs but Figures 1, 4, and 6 (and one curve on fig. 4) are based on contract work.

In Figure 3, in which the output for each of three different contract saw crews working under the same conditions is represented by a curve, it will be noted that there is a considerable difference in output between what may be classed as poor, average, and good saw crews. The size of the timber has a direct bearing upon these differences.

In felling and bucking trees averaging 14 inches diameter breast high the poor and the average saw crew differed but 90 board feet in output per effective hour. The difference is 140 board feet in sawing 24-inch trees and 420 board feet when the crews are cutting 36-inch trees. The same general increase, though more gradual, is found in the output differences between the average and good saw crews at the same diameter sizes. It is obvious that the larger the tree the more ability and technic are demanded of each member of the saw crew in felling it and the more important it is that the sawyers be accustomed to working together as a crew.

A comparison of the output obtained under day and contract work is shown in Figure 4 for ponderosa pine. The curves represent the output per crew per hour in board feet at each 2-inch diameter class from 10 inches to 48 inches, and the corresponding log per thousand groups. According to the curves, the contract crew obtains a greater output per hour by 300 board feet when sawing 20-log per thousand ponderosa pine than does the day crew. As the timber increases in size the difference in output between the two crews also increases. The contract crew attains 500 board feet more

output per hour in sawing 9-log per thousand timber and 620 board feet more in 6-log per thousand timber.

HOW TO COMPUTE SAWING COSTS

The methods of using the graphs shown in Figures 1 to 13 is simple and practical. To apply them to a specific stand of timber or unit of a logging chance the procedure is as follows:

(1) Compute the average number of logs per thousand for the unit. Timber estimates are usually worked up in a manner to show the number of 16-foot logs per thousand by forties or natural logging units. In the ordinary stand of timber it is unnecessary to consider diameter classes separately. However, in stands, for example, having a large percentage of the volume in 14 and 16 inch trees and the remainder in 36 to 40 inch trees, separate consideration must be given to each group. In order to make the sawing data as easy of application as possible, output is as a rule given on the basis of both diameter and logs per thousand. It has been determined in these studies that a variation in height in the same diameter class does not materially affect the scale of the average log. Unless otherwise indicated in the descriptive caption of the graph, the data are applicable only where the average log length is approximately 16 feet.

(2) Determine the gross output per crew per hour for this computed size of timber from the graph which best fits the specific stand and operating conditions. Selection of the proper sawing graph to use to fit the specific chance requires much less experience than in other branches of the logging operation. There is but one kind of equipment with which to do the work in sawing. Slope, brush, and windfall have less effect. Distance from timber to landing needs no consideration. Reference to Table 1 will assist in the selection of the proper graph.

(3) Obtain the gross daily output by multiplying the gross output per hour by the number of hours which will actually be put in on the job each day.

(4) Obtain the net daily output by reducing the above figure by the estimated percentage of defect and breakage. The allowance for probable percentage of defect, breakage, and cull should be determined on the ground during the examination of the logging chance. The percentage of such deductions must be left entirely to the judgment of the man making the examination.

(5) Find the net cost of sawing per thousand by dividing the daily cost of the saw crew by the net daily output. A convenient form of saw-crew costs is shown in Table 13.

The two following examples are given to illustrate the proper use of the sawing graphs:

EXAMPLE A

To find the cost per thousand of sawing western white pine for the size of the timber and particular conditions:

The stand is of the white-pine type and will run 20,000 board feet per acre. The average western white pine tree in the stand is approximately 22 inches diameter breast high, and the timber will run 9 logs per thousand feet board measure. It is estimated as being

about 7 per cent defective. The slope will average about 30 per cent, and the brush may be considered medium in density and size. The sawing is to be done in the winter, and it is estimated that there will be about 2 feet of snow on the ground at the time. The loss for breakage in felling may be considered negligible. Sawing will be done on a day basis, and it is planned to have the crews put in 8 effective hours per day on the job. The cost of the saw crew per effective day is figured at $9. This includes cost of files, oils, and a proportionate charge for time of the filer.

To find the sawing cost per thousand from the output data, proceed as follows:

Selecting Figure 1 as best fitting the specific stand and operating conditions, read the gross output per saw crew per effective hour for 9-log per thousand timber, or 1,025 feet board measure. The gross daily output per saw crew would then be eight times 1,025 feet board measure, or 8,200 feet board measure. To obtain the net daily output, reduce the gross daily output the estimated 7 per cent of defect (8,200 feet board measure reduced 7 per cent equals 7,626 feet board measure). To find the net cost per thousand, divide the daily cost of saw crew ($9) by this net daily output, obtaining $1.18 as cost of sawing per thousand.

EXAMPLE B

To find the cost per thousand of sawing ponderosa pine in a specific stand of timber:

The stand is of the ponderosa pine type running 10 to 12 thousand feet per acre and will fall into two distinctive size classes. Seventy per cent of the volume of the stand is made up of large mature trees 36 to 44 inches diameter breast high or 2.2 logs per thousand feet board measure. These trees are estimated to be 5 per cent defective. The loss from breakage in felling is estimated to be 3 per cent. The remainder, or 30 per cent of the volume of the stand, are young small trees 16 to 18 inches diameter breast high that should average 14 logs per thousand. This class of timber is practically sound, and the loss from breakage in felling is negligible. The slope averages 15 per cent and the brush is classified as light. The sawing is to be done on a day basis, during the summer season. The sawyers are expected to put in eight hours per day on the job, and the total cost of the saw crew per effective day is figured at $8.70.

To find the sawing cost per thousand from the output data proceed as follows:

Because of the wide variations in size of the timber, separate consideration must be given to the two size classes in figuring the sawing cost. Figure 4 (day-labor curve) is selected for use as it best fits the specific stand and operating conditions given in the example. According to the day-labor curve, the 2.2-log per thousand shows a gross output per saw crew per effective hour of 1,275 feet board measure. The gross output per effective hour for the 14-log per thousand timber is given as 785 feet board measure. The gross daily output per saw crew would be eight times the gross output per effective hour, 1,275 ft. b.m. × 8, or 10,200 feet board measure, for the large trees, and 785 ft. b.m. × 8, or 6,280 feet board measure, for the small trees.

Reducing the gross daily output of the large trees by the estimated amount of defect (5 per cent) and breakage loss (3 per cent) gives a net daily output of 9,384 feet board measure. For the small sound trees no reduction need be made.

The net cost of sawing per thousand is then \$8.70÷9,384, or \$0.927 per thousand, for the large trees, and \$8.70÷6,280, or \$1.385 per thousand, for the small trees.

To find the weighted average cost of sawing per thousand in the stand, take 70 per cent (volume of large trees in the stand) of the cost of sawing the large trees and 30 per cent (volume of small trees in the stand) of the cost of sawing the small trees and add the results.

70 per cent of \$0.927	\$0.6489
30 per cent of \$1.385	.4155
Sawing cost per thousand	1.0644

ANALYSIS OF SKIDDING-OUTPUT DATA

The output data for the several methods of skidding most commonly employed in the "Inland Empire" region are given in graphic form as follows: Horse skidding in Figures 14 to 26, tractor skidding in Figures 27 to 32, donkey (ground-line) skidding in Figures 33 to 35, and big-wheel skidding in Figure 36. These graphs are summarized in Table 2.

In contract skidding with horses the unit crew on which the output figures are based consists of the team and teamster and a swamper[5] who may also help in making up the trail of logs. Team and teamster is the standard unit in day work, although in some cases one-half the time of a chainer or dogger is included. Where the logging is all on a day basis the swamping is done as a separate job and usually is completed prior to skidding. All output curves for horse skidding are, unless otherwise designated, applicable to jobs where the average log cut is approximately 16 feet in length. This is the approximate average length of all short logs cut in this region.

Estimates for skidding with tractors ordinarily assume the use of a 10-ton machine with a crew of either one or two men besides the driver. Where the timber is skidded in tree lengths, a tractor unit crew usually consists of a choker setter and a swamper in addition to the driver. Any necessary swamping is done in conjunction with the skidding and is usually limited to brushing out around the felled trees so that the choker can be set speedily and without difficulty. Where the timber is skidded in long-log lengths, a team and teamster are used to bunch the logs in the woods; these then become part of the unit crew. The swampers, one or two in number, work with the bunching team and teamster.

[5] For definitions of logging terms see glossary, p. 85.

TABLE 2.—*Index to skidding*

HORSE SKIDDING

Figure No.	Forest type	Slope [1]	Stand per acre	Season	Organization and equipment	Labor	Surface conditions: Brush	Windfall	Surface	Snow depth	Size of timber
		Per cent	*M ft. b. m.*							*Inches*	*Logs/M*
14	Western white pine	0-15	10-20	Winter	1 chainer per team; tongs, chains, and dogs used.	Day	Medium	Medium	Smooth	10-30	3-26+
15	do	15-30	10-20	do	do	do	do	do	do	10-30	3-25
16	do	30-50	10-20	do	do	do	do	do	do	10-30	3-25
17	do	30-50	25	do	Team, teamster, and swamper; tongs and dogs used.	Contract	Light to medium	Light	do	24-40	3-17
18	Ponderosa pine	0-15	15	Summer	Team and teamster; tongs and chains.	Day	Light	do	Firm and smooth		3-25
19	do	15-30	15	do	do	do	do	do	do		3-25
20	do	30-50	15	do	1 chainer per 2 teams; tongs and chains.	do	Light to medium	do	do		3-26+
21	do	0-15	10	Winter	1 chainer per team; tongs and chains.	do	Medium	do	do	10-20	3-25
22	do	15-30	10	do	Team and teamster; tongs and chains.	do	do	do	do	10-20	3-26+
23	do	15-30	15	do	1 chainer per 2 teams; tongs and chains, small trees in whole lengths.	do	Light	None	Smooth	10-20	3-17
24	Larch-Douglas fir	0-15		Summer	Team and teamster; tongs and chains.	do	do	Light	Firm and smooth		3-17
25	do	0-15	10	Winter	1 chainer per 2 teams; tongs and chains.	do	Medium	do	Medium	10-20	3-26+
26	do	[2] 0-15	10	do	do	do	do	do	do	10-20	3-26+

TRACTOR SKIDDING

32	do	[2] 0-15	10	do	4 men and bunch team, 10-ton tractor, short log.	do	do	do	do		3-12
					DONKEY SKIDDING (11 BY 14 INCH DONKEY)						
33	Western white pine	[2] 0-20	30	Winter	16 men; ground line	Contract	Light to medium	Light to medium.	Medium	30-40	3-12
34	do	0-20	30	do	17 men; ground line	do	do	do	do	30-40	3-17
35	do	[2] 20, 20	8	do	16 men; ground line	do	Light to heavy	Light to heavy.	do	30-40	5.5
					BIG-WHEEL SKIDDING						
36	Ponderosa pine	[4]		Summer	5 men, 2 sets wheels, 8 horses	Day	Light	Light	Medium		8

[1] Downhill unless otherwise noted. [2] Uphill. [3] Ground frozen. [4] Level.

TABLE 2.—*Index to skidding*

HORSE SKIDDING

Figure No.	Forest type	Slope[1]	Stand per acre	Season	Organization and equipment	Labor	Surface conditions: Brush	Surface conditions: Windfall	Surface conditions: Surface	Surface conditions: Snow depth	Size of timber
		Per cent	*M ft. b. m.*							*Inches*	*Logs/M*
14	Western white pine	0-15	10-20	Winter	1 chainer per team; tongs, chains, and dogs used.	Day	Medium	Medium	Smooth	10-30	3-26+
15	do	15-30	10-20	do	do	do	do	do	do	10-30	3-25
16	do	30-50	10-20	do	do	do	do	do	do	10-30	3-25
17	do	30-50	25	do	Team, teamster, and swamper; tongs and dogs used.	Contract	Light to medium	Light	do	24-40	3-17
18	Ponderosa pine	0-15	15	Summer	Team and teamster; tongs and chains.	Day	Light	do	Firm and smooth		3-25
19	do	15-30	15	do	do	do	do	do	do		3-25
20	do	30-50	15	do	1 chainer per 2 teams; tongs and chains.	do	Light to medium	do	do		3-26+
21	do	0-15	10	Winter	1 chainer per team; tongs and chains.	do	Medium	do	do	10-20	3-25
22	do	15-30	10	do	Team and teamster; tongs and chains.	do	do	do	do	10-20	3-26+
23	do	15-30	15	do	1 chainer per 2 teams; tongs and chains, small trees in whole lengths.	do	Light	None	Smooth	10-20	3-17
24	Larch-Douglas fir	0-15		Summer	Team and teamster; tongs and chains.	do	do	Light	Firm and smooth		3-17
25	do	0-15	10	Winter	1 chainer per 2 teams; tongs and chains.	do	Medium	do	Medium	10-20	3-26+
26	do	[1] 0-15	10	do	do	do	do	do	do	10-20	3-26+

TRACTOR SKIDDING

32	do	[2] 0-15	10	do	4 men and bunch team, 10-ton tractor, short log.	do	do	do	do		3-12
DONKEY SKIDDING (11 BY 14 INCH DONKEY)											
33	Western white pine	[2] 0-20	30	Winter	16 men; ground line	Contract	Light to medium	Light to medium.	Medium	30-40	3-12
34	do	0-20	30	do	17 men; ground line	do	do	do	do	30-40	3-17
35	do	[2] 20, 20	8	do	16 men; ground line	do	Light to heavy	Light to heavy.	do	30-40	5.5
BIG-WHEEL SKIDDING											
36	Ponderosa pine	([4])		Summer	5 men, 2 sets wheels, 8 horses	Day	Light	Light	Medium		8

[1] Downhill unless otherwise noted. [2] Uphill. [3] Ground frozen. [4] Level.

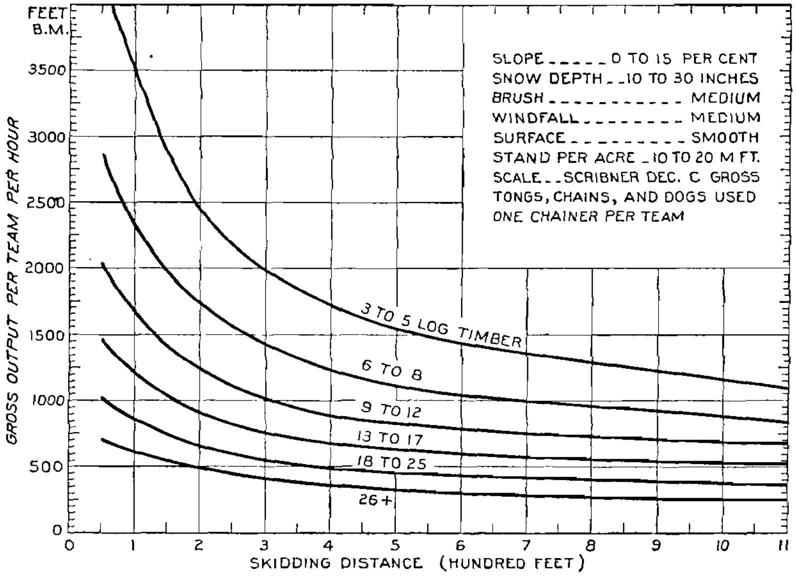

FIGURE 14.—Horse-skidding output, in western white pine type, little slope. Day labor, winter work. Basis: 770 M feet, 3,851 trips. Data collected winter, 1919, 1920, 1921, and 1922

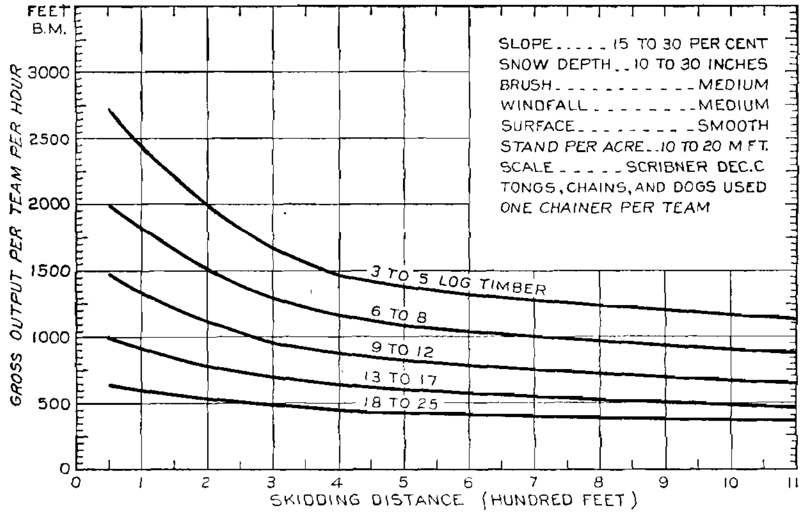

FIGURE 15.—Horse-skidding output, in western white pine type, moderate slope. Day labor, winter work. Basis: 976 M feet, 3,456 trips. Data collected winter, 1919, 1920, 1921, and 1922

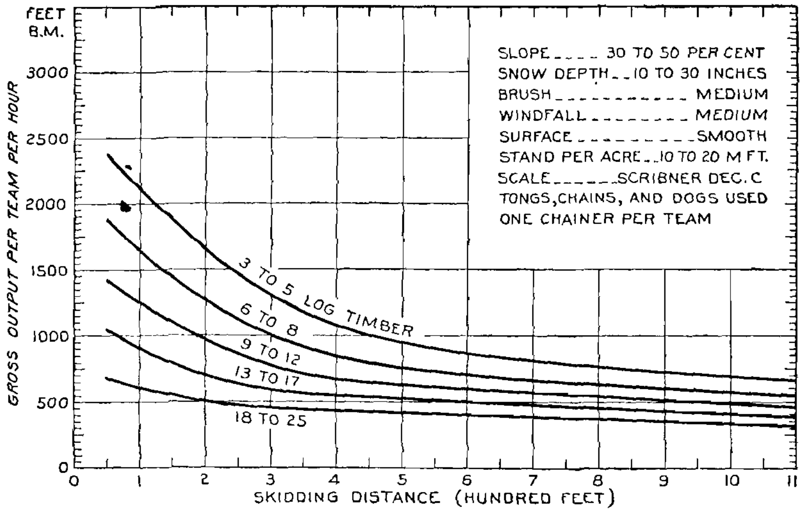

FIGURE 16.—Horse-skidding output, in western white pine type, steep slope. Day labor, winter work. Basis: 598 M feet, 1,610 trips. Data collected winter, 1919, 1920, 1921, and 1922

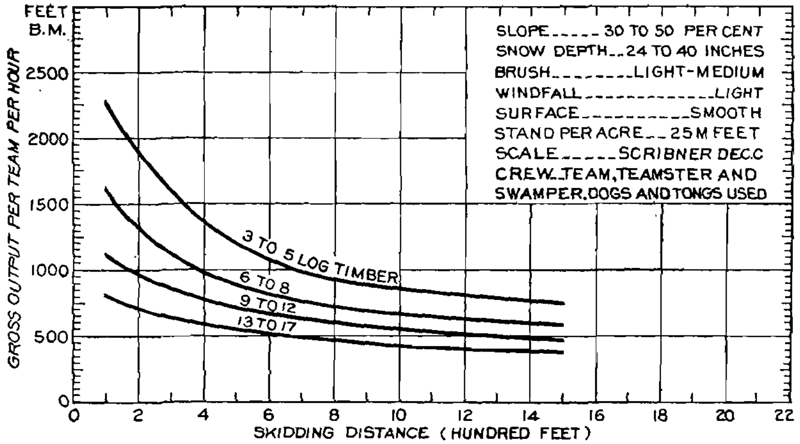

FIGURE 17.—Horse-skidding output, in western white pine type, steep slope. Contract skidding and swamping, winter work. Basis: 515 M feet. Data collected winter, 1921

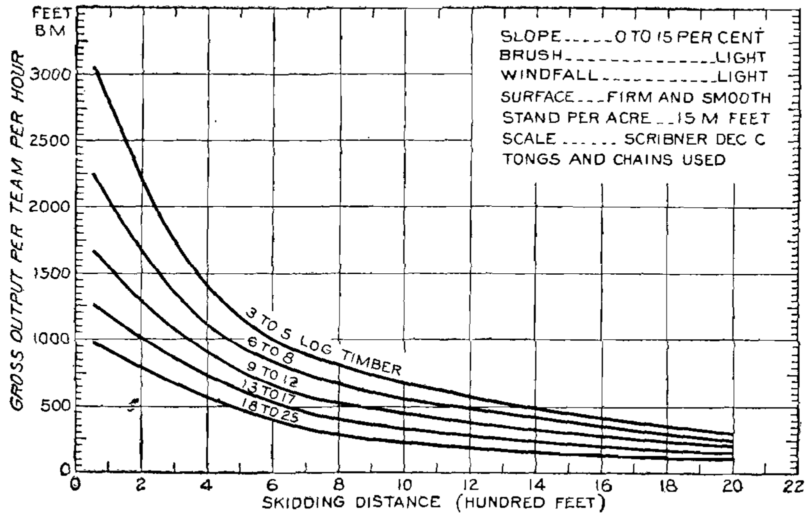

FIGURE 18.—Horse-skidding output, in ponderosa pine type, little slope. Day labor, summer work. Basis: 750 M feet

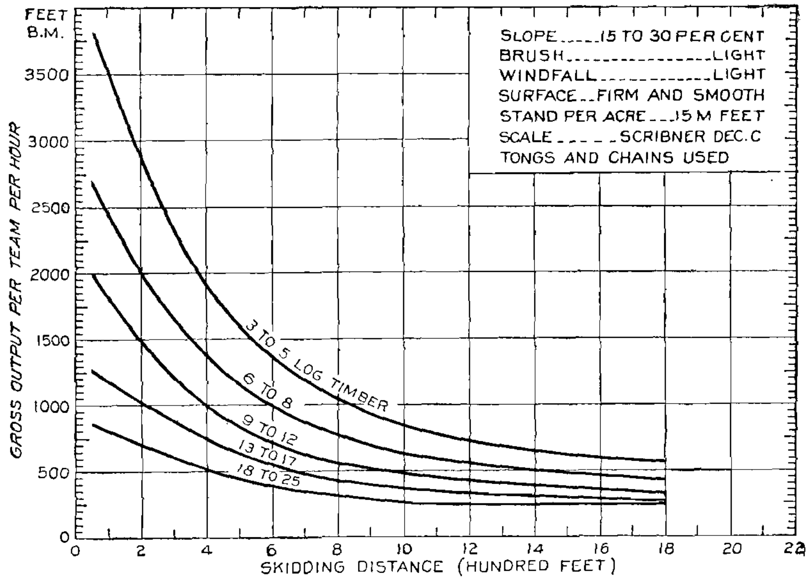

FIGURE 19. Horse-skidding output, in ponderosa pine type, moderate slope. Day labor, summer work. Basis: 198 M feet, 930 trips. Average scale per trip 213 feet. Data collected summer, 1919

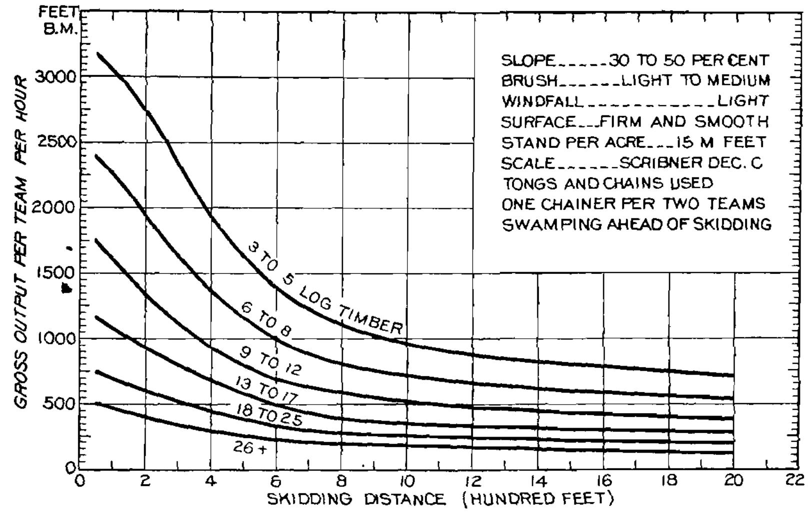

FIGURE 20.—Horse-skidding output, in ponderosa pine type, steep slope. Day labor, summer work. Basis: 491 M feet, 1,853 trips. Data collected July and August

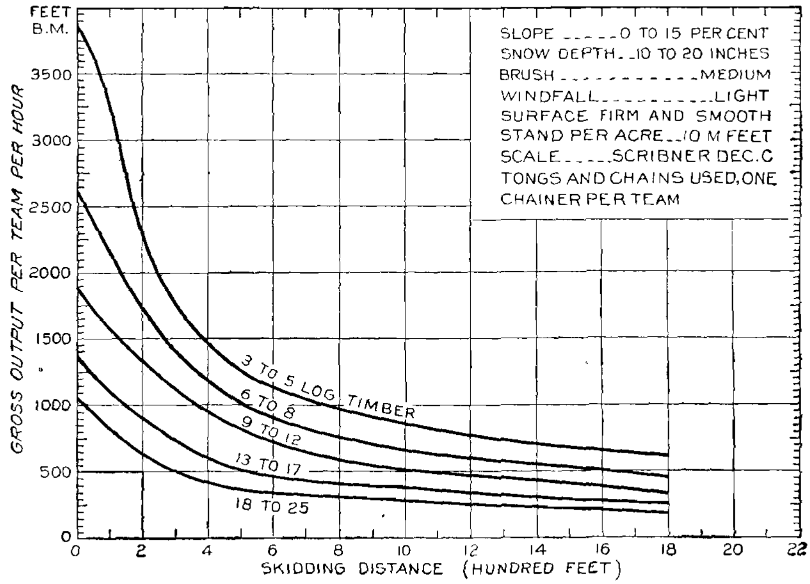

FIGURE 21.—Horse-skidding output, in ponderosa pine type, little slope. Day labor, winter work. Basis: 337 M feet, 1,500 trips. (Curves extended, beyond 1,200 feet distance.) Data collected December, January, and February

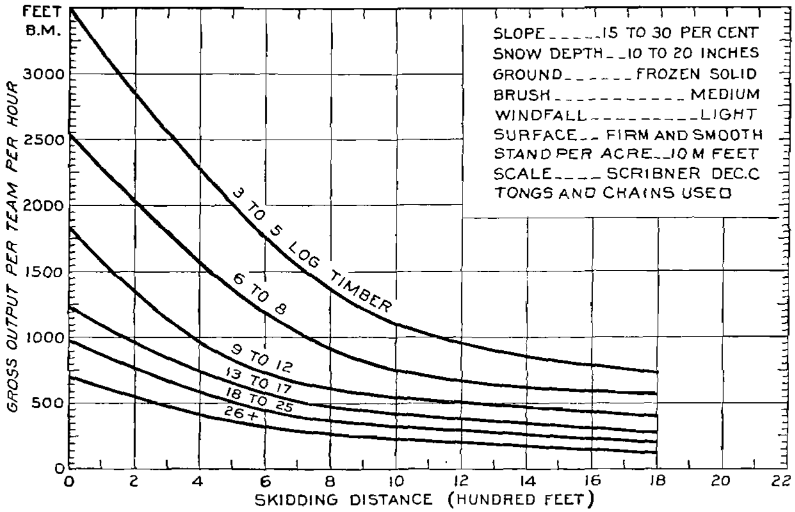

FIGURE 22.—Horse-skidding output, in ponderosa pine type, moderate slope. Day labor, winter work. Basis: 234 M feet, 1,100 trips. (Average scale per trip 213 feet.) Data collected December, January, and February

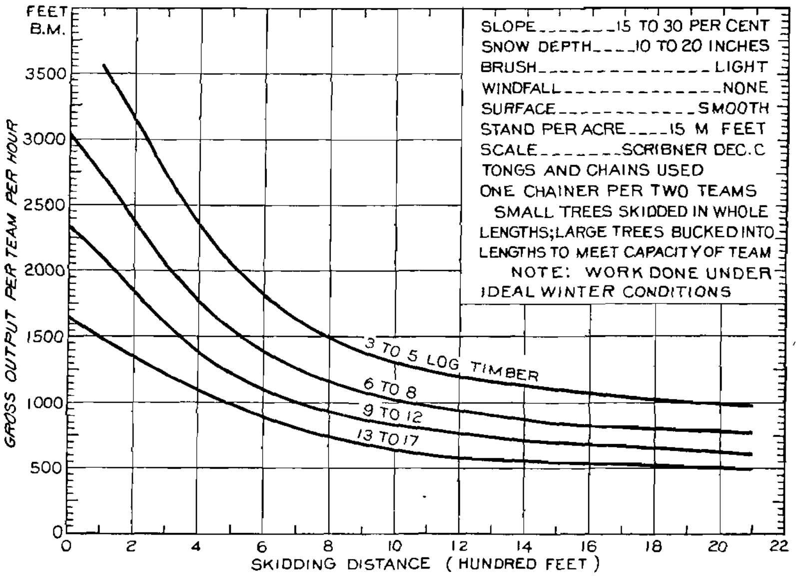

FIGURE 23.—Horse-skidding output, in ponderosa pine type, moderate slope. Day labor, winter work. The work was done under ideal winter conditions. Basis: 258 M feet, 509 trips. Data collected January and February

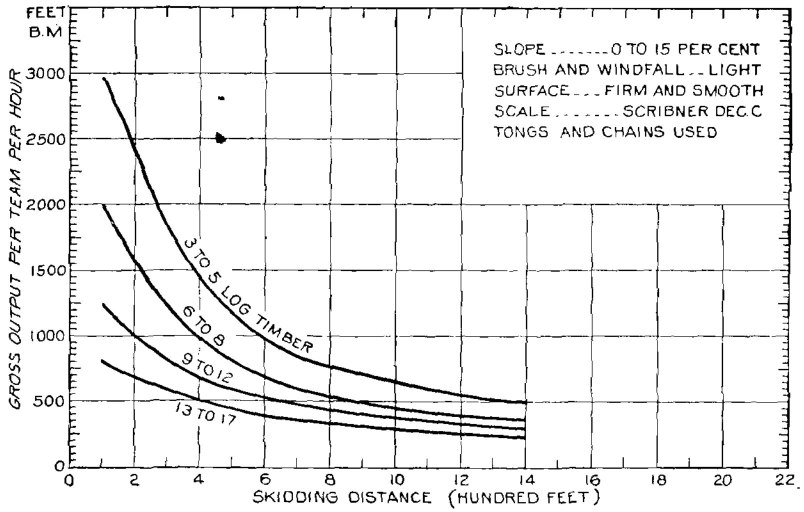

FIGURE 24.—Horse-skidding output, in larch-Douglas fir type, little slope. Day labor, summer work. Basis: 167 M feet, 1,100 trips. Data collected September, 1920

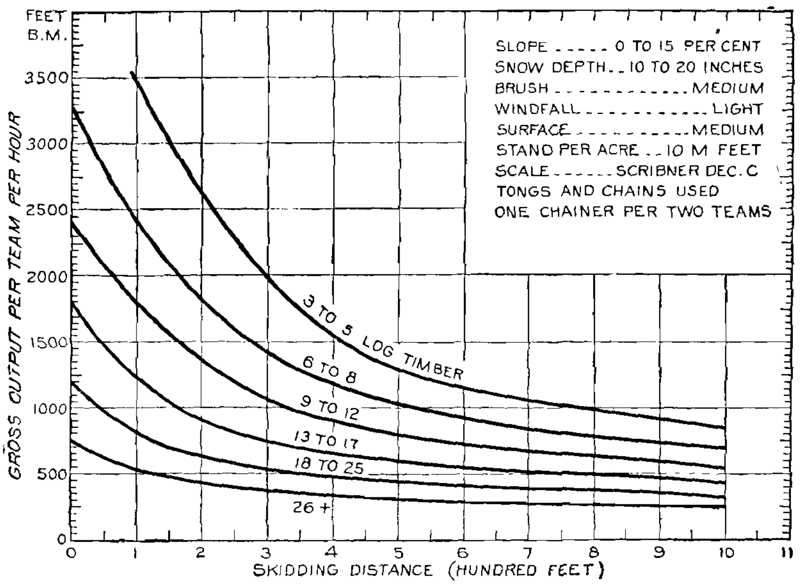

FIGURE 25.—Horse-skidding output, in larch-Douglas fir type, little slope. Day labor, winter work under ideal operating conditions in 1921 and average in 1922. Basis: 1,204 M feet, 9,689 trips. Data collected January and February, 1921 and 1922

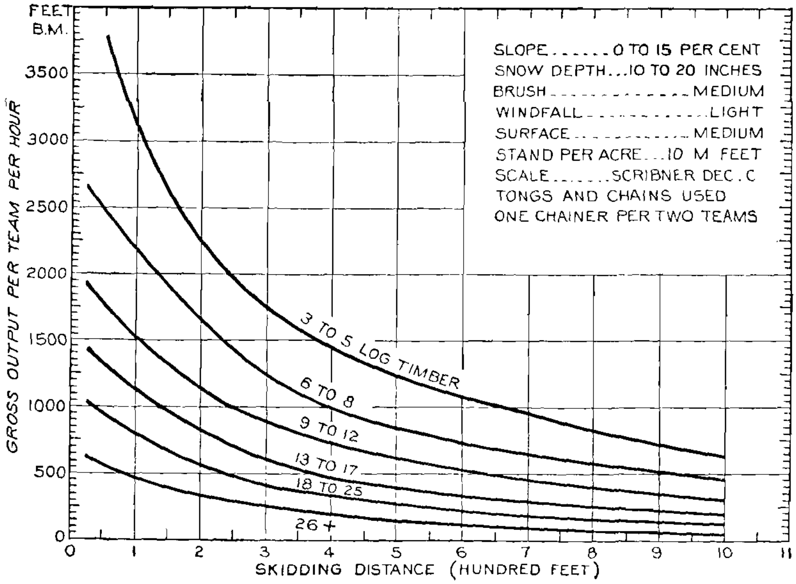

FIGURE 26.—Horse-skidding output, in larch-Douglas fir type, little slope, uphill. Day labor, winter work under ideal conditions. Basis: 192 M feet, 1,666 logs. Data collected January and February, 1922

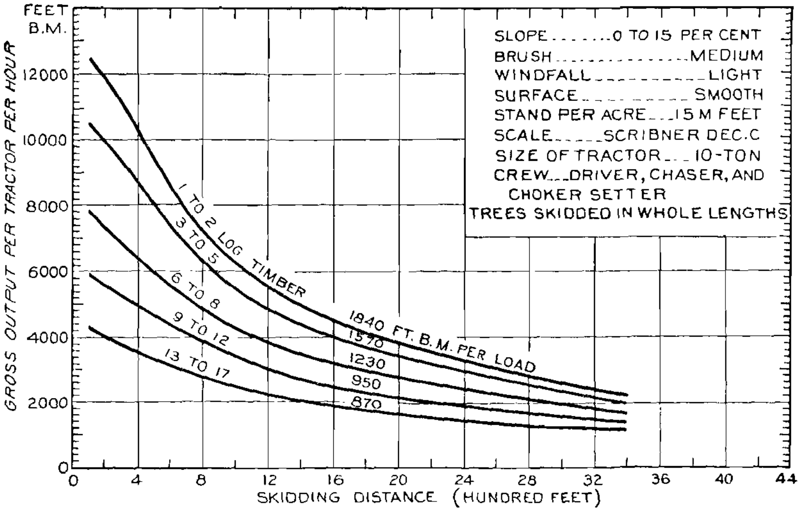

FIGURE 27.—Tractor-skidding output, in ponderosa pine type, little slope. Day labor. Summer work. Basis: 764 M feet, 534 trips. Data collected 1921 and 1922

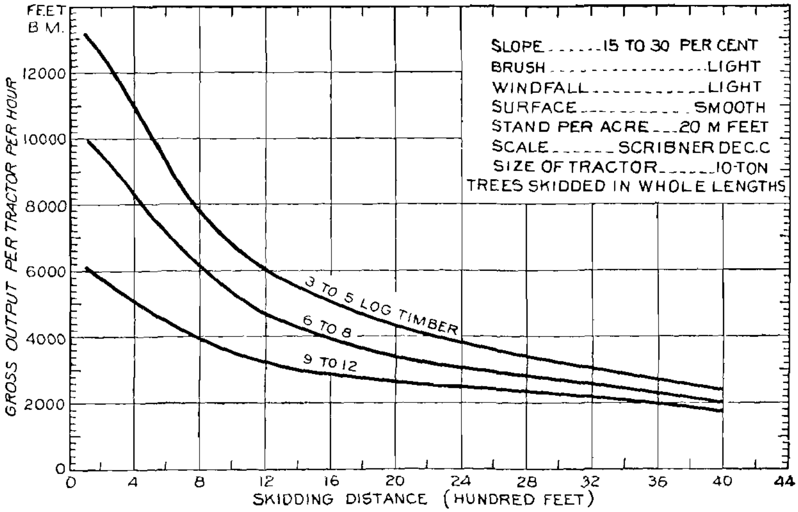

FIGURE 28.—Tractor-skidding output, in ponderosa pine type, moderate slope. Day labor. Summer work. Basis: 860 M feet, 363 trips. Data collected September and October, 1921

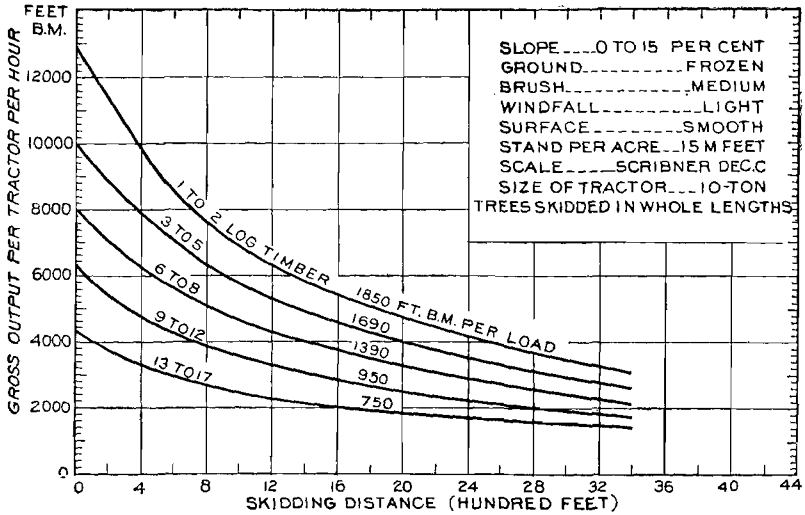

FIGURE 29.—Tractor-skidding output, in ponderosa pine type, little slope. Day labor. Winter work. Basis: 1,635 M feet, 1,074 trips. Data collected January and February, 1923

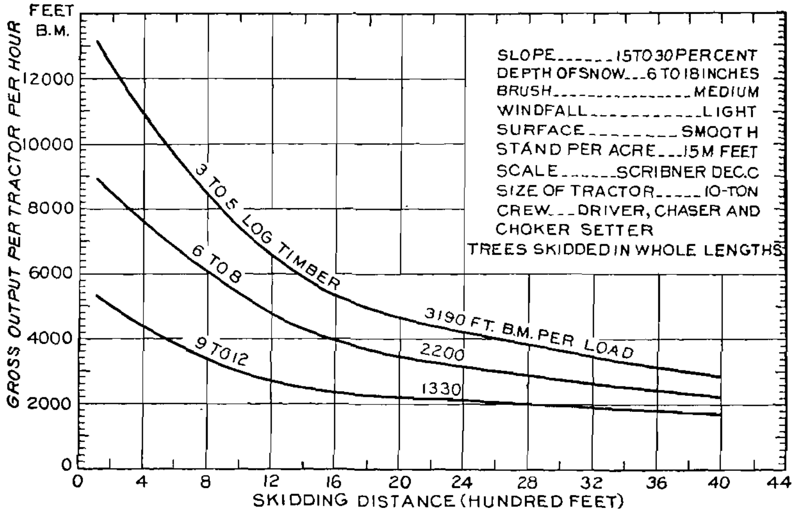

FIGURE 30.—Tractor-skidding output, in ponderosa pine type, moderate slope. Day labor. Winter work. Basis: 782 M feet, 290 trips. Data collected February and March, 1923

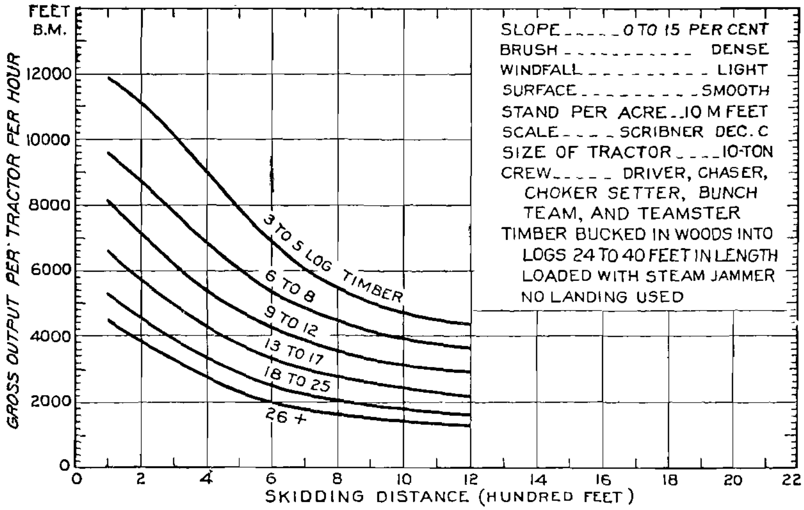

FIGURE 31.—Tractor-skidding output, in ponderosa pine type, little slope. Day labor. Summer work. Basis: 392 M feet, 529 trips. Data collected August and September, 1921.

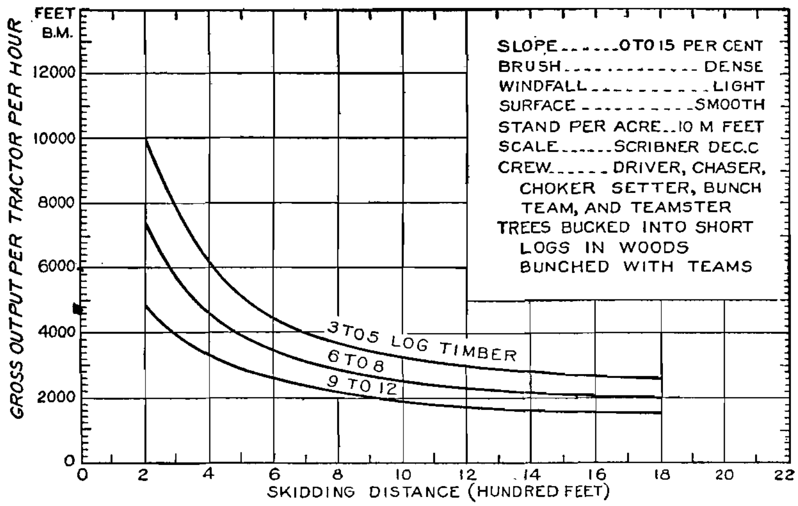

FIGURE 32.—Tractor-skidding output, in ponderosa pine type, little slope, uphill. Day labor. Basis: 230 M feet, 219 trips. Data collected November, 1921

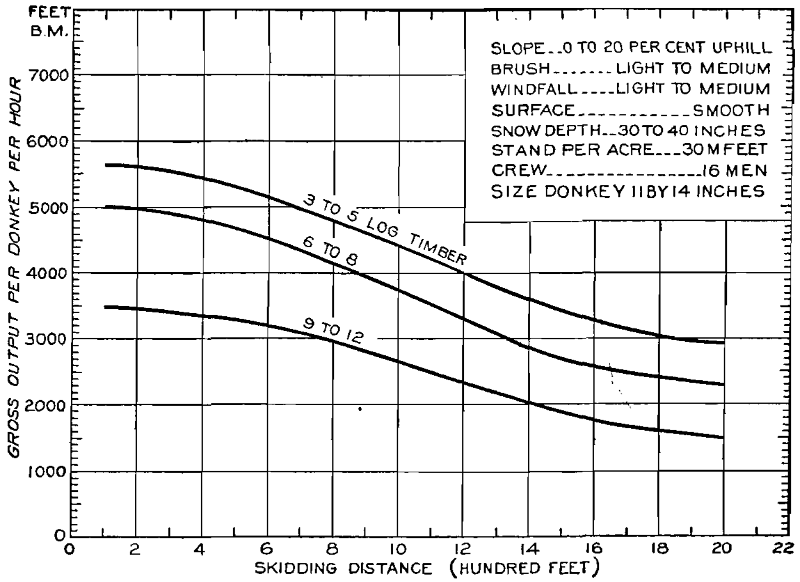

FIGURE 33.—Donkey-skidding (ground-line) output, in western white pine type, little to fair slope, uphill. Contract labor, winter work. Basis: 264 M feet, 128 trips. Data collected January and February, 1921

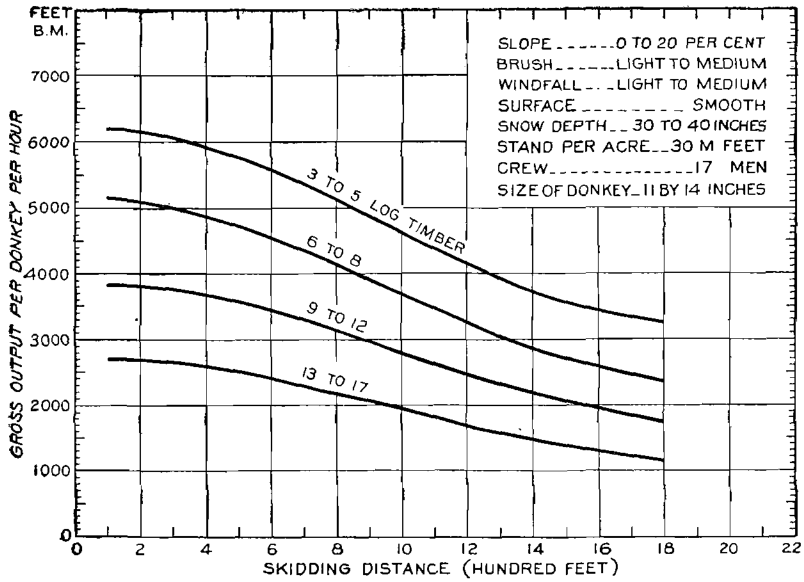

FIGURE 34.—Donkey-skidding (ground-line) output, in western white pine type, little to fair slope, downhill. Contract labor, winter work. Basis: 435 M feet, 284 trips. Data collected January and February, 1921

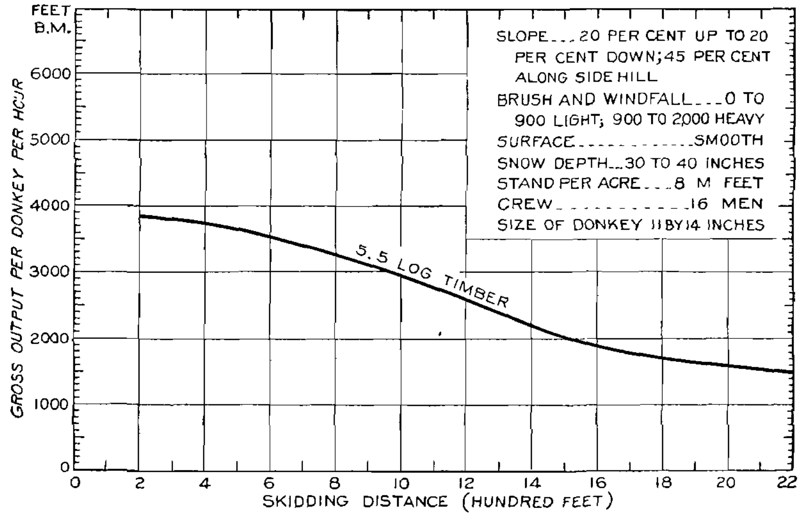

FIGURE 35.—Donkey-skidding (ground-line) output, in western white pine type, easy slope up, and down, also along steep side hill. Contract labor, winter work. Basis: 74 M feet, 45 trips. Data collected January and February, 1920

The unit organization for ground-line donkey skidding includes, besides the engine crew, choker setters, and whistle punk, the landing saw crews and the loading crew. Sixteen men compose the ordinary crew. The timber is skidded in tree lengths and bucked into short or double-length logs at the landing. Skidding by this method is usually on a contract basis.

In big-wheel skidding the unit crew consists of 5 men with 2 sets of wheels and 8 horses. The 5 men include 2 teamsters, 2 loaders, and a landing man. Individual loads are bunched in the wheel roads by independent crews consisting of team, teamster, and a chainer or cant-hook man.

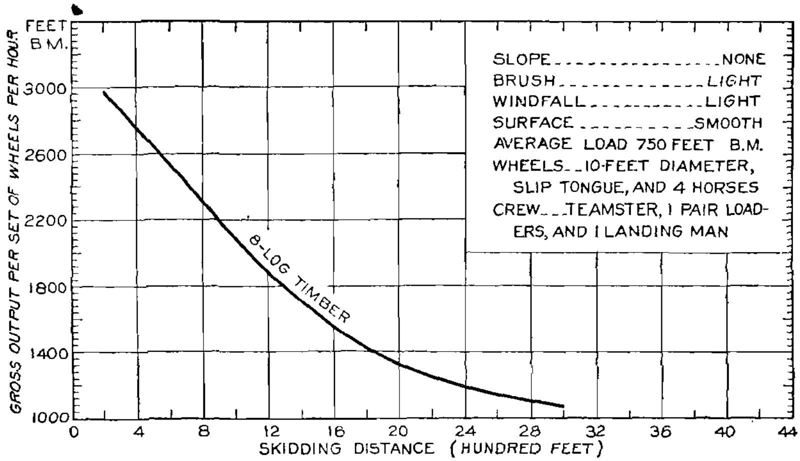

FIGURE 36.—Big-wheel-skidding output, in ponderosa pine type, on level ground. Day labor, summer work. Average time per trip required for loading, unloading, and delays, 9.8 minutes

For each of the several methods studied the output data have been segregated by such natural factors as forest type, stand per acre, size of timber, slope, surface, windfall and brush, and season of the year. Pay basis (day or contract), the make-up of the crew, and the amount of footage upon which the data are based are likewise stated in the legend of each graph or on the graph itself.

EFFECT OF NATURAL FACTORS ON SKIDDING

The size of the timber, the distance from the landing, the slope, and the operating season very definitely affect the output in all methods of log transportation. Some result in a larger, others in a smaller, output. A change in one of these factors may modify the influence of the others. The effect of such reactions is important. A thorough study of each set of skidding data is recommended. A brief analysis here, however, of a number of the different skidding graphs will be made to emphasize the effect of these different factors upon the output. In order to help in the discussion the output per effective hour has been read from a full set each of horse and tractor skidding graphs and is presented in Table 3.

TABLE 3.—*Skidding output per team per effective hour (gross scale), by degree of slope and size of timber, ponderosa pine, work on day basis*

Skidding distance (feet)	Operating season	Slope 0–15 per cent			Slope 15–30 per cent			Slope 30–50 per cent		
		3–5 logs per M	9–12 logs per M	18–25 logs per M	3–5 logs per M	9–12 logs per M	18–25 logs per M	3–5 logs per M	9–12 logs per M	18–25 logs per M
		HORSE SKIDDING [1]								
		Bd. ft.	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*
100	Summer	2,790	1,525	910	3,510	1,800	800	3,040	1,615	690
	Winter	3,250	1,585	815	3,165	1,590	875	----	----	----
200	Summer	2,200	1,275	785	2,865	1,470	700	2,750	1,340	600
	Winter	2,265	1,325	635	2,865	1,360	780	----	----	----
400	Summer	1,400	900	565	1,910	1,000	520	1,925	930	445
	Winter	1,450	940	410	2,290	975	590	----	----	----
600	Summer	1,010	670	400	1,350	720	390	1,390	690	335
	Winter	1,125	700	330	1,775	750	450	----	----	----
800	Summer	800	525	290	1,040	560	300	1,100	585	280
	Winter	965	585	310	1,375	615	370	----	----	----
1,000	Summer	665	430	220	845	480	260	965	520	260
	Winter	860	520	280	1,090	550	325	----	----	----
1,200	Summer	575	370	175	730	425	250	885	470	240
	Winter	775	470	260	960	515	300	----	----	----
1,600	Summer	410	270	125	600	360	250	785	430	220
	Winter	655	375	200	790	440	230	----	----	----
1,800	Summer	350	225	115	565	330	250	750	410	210
	Winter	600	320	175	735	400	200	----	----	----
		TRACTOR SKIDDING [2]								
200	Summer	10,025	5,625	----	12,550	5,775	----	----	----	----
	Winter	8,900	5,400	----	12,350	4,975	----	----	----	----
400	Summer	8,750	5,000	----	11,000	5,075	----	----	----	----
	Winter	7,875	4,725	----	10,850	4,350	----	----	----	----
800	Summer	6,350	3,875	----	7,900	3,950	----	----	----	----
	Winter	6,300	3,825	----	8,375	3,350	----	----	----	----
1,200	Summer	4,875	3,050	----	6,075	3,250	----	----	----	----
	Winter	5,275	3,300	----	6,550	2,700	----	----	----	----
1,600	Summer	4,000	2,500	----	5,000	2,875	----	----	----	----
	Winter	4,600	2,850	----	5,300	2,350	----	----	----	----
2,000	Summer	3,400	2,150	----	4,350	2,650	----	----	----	----
	Winter	4,000	2,500	----	4,650	2,175	----	----	----	----
2,400	Summer	2,900	1,850	----	3,825	2,475	----	----	----	----
	Winter	3,525	2,200	----	4,200	2,075	----	----	----	----
3,000	Summer	2,350	1,575	----	3,200	2,200	----	----	----	----
	Winter	2,950	1,875	----	3,625	1,925	----	----	----	----

[1] From figs. 18, 19, 20, 21, and 22.
[2] From figs. 27, 28, 29, and 30.

SIZE OF TIMBER

The effect of the size of the timber upon output is evident in every set of skidding data; size exerts a real influence upon this phase of the logging cost. It is often the case that up to a certain limit just so many pieces, irrespective of size, can be handled per day. The following example will show the direct effect of size of timber upon skidding output:

Summer skidding with horses in the ponderosa pine type on 0 to 15 per cent slopes shows the output (Table 3, column 3, data from Figure 18) in 3 to 5 log per thousand timber skidded a distance of 100 feet to be three times as much as in 18 to 25 log timber. The reason is obvious. Let it be supposed that the team can handle but one of the large logs efficiently per trip. The average log in the 3 to 5 log run will scale approximately 250 board feet. To get the same scale per trip in the small 18 to 25 log timber, 5 logs would have to be bunched and chained or dogged together. Not much, if any, more time would be needed to hook on to a large log than to one of the

small ones; the hooking-on time may therefore be said to be five times as great for small logs as for large. The 5-log trail would obviously represent a larger bulk than the 1-log trail, but it also represents a considerably greater weight. Owing to their greater percentage of sapwood, small logs weigh more per board or cubic foot than do large ones. Green western white pine logs, running 3 to 7 to the thousand, for instance, weigh only 6,000 pounds per thousand feet, as compared with 7,500 pounds for 8 to 15 log timber. However, it is bulk rather than weight that limits the scale of each load. The trip time from the woods to the landing should if anything favor the bigger timber.

In general, therefore, a smaller output as the size of the material decreases may be attributed to the greater amount of time required to make up and unhook the load and to the smaller board-foot volume that can be taken as the bulk of the load increases. The greatest relative difference in output will naturally occur where bulk is the greatest limiting factor in transportation, as with donkey, tractor, and big-wheel skidding. The smallest difference exists in methods where either the tractive or supporting power, rather than bulk, is the limiting factor, as with autotruck, wagon, sleigh, or dray haul, and horse skidding on the ground. With the tractor, and to a still greater extent with the donkey engine, a limit in the number of pieces which can be skidded per load is reached in the smaller material before the weight has an appreciable effect. A greater difference is therefore found in most cases between the output for small and large timber in tractor skidding than in horse skidding. The same relation exists between donkey skidding and tractor skidding.

It is apparent from the foregoing discussion that skidding output decreases rapidly as the size of the timber decreases. The cost per thousand for small timber is, therefore, much greater than that for large timber when skidding is carried on under the same conditions and by the same method. This is common knowledge and in itself is of value to the operator only in figuring the difference in cost per thousand of skidding different-size timber. Such information is, however, necessary in making appraisals, estimating job costs, and setting the price for contract work. Furthermore, this decrease in output of smaller timber is greater in donkey and tractor skidding than in horse skidding. More advantage, therefore, is gained by the use of the first two methods in the larger timber only. This in an important finding, for it enables the operator or logging engineer to select the method and equipment that will assure the most economical operation for a given size of timber.

SKIDDING DISTANCE

As the actual distance over which the logs or trees must be moved from stump to landing increases, the output, of course, decreases. This is to be noted in every method of transportation discussed subsequently. It may be logically assumed that it takes the same amount of time to make up a load or trail in the woods and unhook it at the landing at a distance 100 feet back as, say, 1,600 feet back, since the scale or the number of the logs in the load is not usually reduced as the distance from the landing increases. The output must then vary in almost direct proportion to the time it takes to

move the load between the stump and the landing. The variation is greatest, however, in horse skidding, for the animals must be rested at increasingly frequent intervals as the distance over which the load must be hauled increases. To illustrate, the horse-skidding output per team per hour in 3 to 5 log timber (Table 3) when the landing is 200 feet away is 5.37 times the output when it is 1,600 feet away; with tractors under the same conditions the output is but 2.51 times as much.

On level ground the difference in output between different sizes of material varies to a considerable degree according to the distance that the material is moved. The greatest advantage of handling large logs rather than small logs is found in the shorter skidding or hauling distances. As the distances increases, this difference decreases. A thorough understanding of the effect upon output of distance alone and of distance in combination with the other factors is important. Distance, unlike size of timber and percentage of slope, can be changed to advantage by the proper spacing of minor transportation improvements. It should be noted that on level ground the effect of distance in decreasing output is more marked in large than in small timber. That is to say, the already relatively lower output in skidding small logs, evident over short hauls, does not decrease with distance in the same proportion that the output of large logs decreases.

SLOPE

The difference in output between large logs and small logs that is evident on level ground increases considerably with increase in slope, in varying degree according to the method of skidding. With donkey skidding, autotruck or sleigh hauling, and donkey or tractor trailing in chutes, transporting logs on slopes has but little advantage over transportation on nearly level ground. In fact, anything over a very moderate slope causes a reduction in output for some of these methods, since more time may be required to return empty and no increase in speed of travel or size of load may result from having slope with the traffic. This would be particularly true with small material. On the other hand, in some of the largest timber in this region a moderate slope is of some advantage under the methods just mentioned.

Slope causes the greatest differences in output of various sizes with such methods as horse or tractor skidding and horse trailing. The table of outputs (Table 3) shows, with but one exception, that the output in 3 to 5 log per thousand timber is greater on 15 to 30 per cent slopes than on 0 to 15 per cent slopes, for both horses and tractors, at all distances and during both operating seasons. The same is true in 9 to 12 log timber when skidded with horses, but in tractor skidding in the winter a greater output in this size timber is obtained on the gentle slopes than on the steeper slopes. In very small timber the influence which slope has upon output is varied to a considerable degree by the distance over which the logs must be hauled.

On slopes of 45 to 60 per cent, horses skid, per trip, about the same number of logs, except in large timber. The output ratio between sizes is here almost directly in proportion to the difference in

scale between two average logs of these sizes, particularly for the shorter distances. For the longer distances a greater difference exists between the outputs of large and small timber than on level ground. Thus it may be seen that slope favors large material at all distances but particularly at the greater distances. The advantage is greater also where horses are used for skidding. The number of logs which may be horse skidded per trip on a 45 to 60 per cent slope is usually limited only by the number of trail dogs which the team can take back up the hill.

After a certain percentage of slope is reached, the ratio of output between different-sized timber remains practically constant. This is the percentage of slope at which the most favorable operation starts. It comes earliest under skidding methods where tonnage is a factor, as in hauling by autotruck; next under methods in which slope is of no material advantage, as in donkey skidding; third, in tractor skidding or horse trailing in chutes, which are most effective over slopes of 20 to 30 per cent; and last in horse skidding over slopes of about 45 to 60 per cent. All such ideal slope conditions are for summer weather.

In summing up the effects of slope it may be said that since slope favors large timber at all distances but particularly at the greater distances, the intervals between secondary transportation routes in large timber may thus be greater on steep slopes than on level ground.

OPERATING SEASON

The relation between skidding output and the various natural factors has so far been considered mainly as it prevails in average summer weather. On frozen ground and snow, these relationships change to a very marked degree. Frozen ground covered with snow favors output most on level ground, in large timber, and with long hauls. These are the conditions under which tractive power counts most. Thus horse skidding, being the most limited by lack of power, would have relatively the greatest increase in output in the winter season. This is clearly illustrated later in Table 6.

Winter work on level ground requires on an average about the same tractive power as summer work on 15 to 30 per cent slopes. The advantage offered by winter work diminishes continually as size of timber or distance decreases and as slope increases. A point in the combination of these other factors is finally reached beyond which winter conditions not only prove to be a disadvantage but make the cost of the work prohibitive.

Constant fluctuations in weather conditions result in a good deal of variation in output from day to day. Changing depth of snow is one of the principal causes. Output data based on different depths of snow can neither be obtained nor applied. An average of the various depths under which the work is commonly done must therefore be considered.

Until snow exceeds a depth of 18 or 20 inches, it does not perceptibly cut down skidding output, provided the trees have been felled on top of the snow. Beyond this depth, especially if the snow is packed or crusted, more or less time is lost in breaking trails

and choking logs. The proportion of time lost in these operations is in inverse ratio to the skidding distance and size of timber. Additional time required for setting chokers is approximately the same for each piece, irrespective of size—the fewer logs per thousand feet the less time per thousand is lost in setting chokers. Also, the shorter the trip the greater the proportion of the trip time used in choking and in breaking a trail through unbroken snow. Usually accumulation is gradual; snow seldom falls in such quantities during one night as to affect appreciably a going operation. Breaking through the snow on each trip from one log to the next is practically the only inconvenience caused by a cover of 2 feet.

Briefly, in winter on frozen ground and snow, a greater proportional skidding output is obtained in large timber and with long hauls. Advantage should be taken of seasonal conditions. Level areas of large timber at greatest distance from improved transportation can be set aside for winter work. A material saving may thus be realized both in moving logs from stump to landing and in the construction of improvements. Since a comparatively longer skidding distance is practical in winter, such improvements as chutes and railroad spurs can in many cases be dispensed with by skidding certain areas in winter rather than in summer.

HOW TO COMPUTE SKIDDING COSTS

Output data for skidding are easily and accurately applied. Their use in determining the cost of skidding on a particular logging unit requires the following steps:

(1) Calculate the average skidding distance for each component part of the unit. This calculation must take into consideration slope, distance between skidways, direct surface distance from tree to skidway as compared with the actual surface distance followed in skidding, and uniformity of timber distribution over the area with relation to distance from the landing points. As a rule, skidways are built at intervals of 200 to 400 feet along the transportation route. The actual skidding distance from point to point ranges from 15 to 30 per cent more than the direct distance with an average of about 20 per cent. Consequently the average skidding distance for an area having a uniform distribution of stand may be obtained by taking 60 per cent of the greatest average direct distance from stump to route of transportation. The biggest trees and largest yields per acre are usually on the lower slopes and bottoms. Such unequal distribution of the timber stand affects the average skidding distance. The following example is given to illustrate the method used to compensate for this influence.

To find the average skidding distance for a maximum skidding distance of 1,200 feet, with 60 per cent of the timber lying within the first 600 feet, first take 60 per cent of 600 feet, or 360 feet, for the 600-foot strip. Within the second part of the strip, also 600 feet wide, the average skidding distance would be 60 per cent of 600 feet, as in the first part, or 360. But these logs must also traverse the first or closest half of the area, which has a direct width of 600 feet, or an actual average skidding distance of 720 feet (20 per cent more than the direct distance). Adding the 720 feet necessary to traverse

the first part and the 360 feet for the second gives a total average skidding distance within the second part of 1,080 feet.

If 60 per cent of the timber must be skidded 360 feet and 40 per cent 1,080 feet, then: $(360 \times 0.60) + (1{,}080 \times 0.40) = 648$ feet, the actual average skidding distance for the area.

(2) Compute the average number of logs per thousand for each subdivision or skidding unit. Where trees or double-length logs are handled in tractor or donkey operations, the logs per thousand should be determined in terms of the number of 16-foot logs per thousand, *irrespective* of the length into which the timber may be bucked.

(3) Determine for each skidding unit the gross output per hour for the average skidding distance from the proper logs-per-thousand curve which best fits the specific operating conditions. Reference to Table 2 will assist in this selection.

(4) Obtain the gross daily output by multiplying the gross output per hour by the number of effective hours per day. Effective hours per day are the measure of time actually put in on the job each day, depending on the distance to work and the standard length of the working day. On the basis of an 8-hour day, effective time usually ranges from 7 to 7¾ hours.

(5) Obtain the net daily output by reducing the above figure by the estimated percentage of defect.

(6) Find the net cost of skidding per thousand feet by dividing the daily cost of the unit skidding crew by the net daily output. Skidding-crew cost records are illustrated by Tables 14, 15, 18, and 19.

The following examples are given to illustrate the proper use of the graphs:

EXAMPLE A

To find the cost per thousand of skidding with horses with a specified size and species of timber and conditions of operation:

In a stand of ponderosa pine running 15,000 feet board measure per acre, the timber averages between six and eight logs per thousand and is estimated as 5 per cent defective. Brush and windfall over the area are light, but the slope is about 40 per cent. The average skidding distance is 600 feet. It is planned to log the area in the summer. Work will be done on a day basis of pay, and the men will be expected to put in eight hours per day on the job. The area will be swamped before skidding.

To find the skidding cost per thousand proceed as follows:

According to the horse-skidding graph in Figure 20, selected as best fitting the given stand and operating conditions, 6 to 8 log timber shows the gross output per team per effective hour over an average distance of 600 feet to be 1,000 board feet, making the gross daily output per team 8,000 feet board measure. Reducing this gross daily output by the estimated 5 per cent defect yields a net daily output of 7,600 feet board measure. To find the net cost of skidding per thousand divide the daily cost of the skidding crew, which in this case includes a team and teamster and half time of a dogger (Table 18) by the net daily output (7,600 feet board measure). The result is a net skidding cost of $1.27 per thousand.

EXAMPLE B

To find the cost per thousand of skidding with tractors with specified size and species of timber and conditions of operation:

In a stand of ponderosa pine running 15,000 feet board measure to the acre, in moderately heavy brush and on moderately level ground (the slope in no place being more than 15 per cent) large timber averaging four logs per thousand, with 15 per cent defect, is to be skidded in tree lengths by a unit crew of tractor and driver, chokerman, and swamper, putting in nine hours a day on the job. The logging will be done during the summer. The average skidding distance is 1,600 feet.

To find the skidding cost per thousand, consult the tractor-skidding graph in Figure 27 (selected as best fitting the specific stand and operating conditions). Here, 4-log timber has a gross output per tractor per effective hour of 4,000 feet board measure, or 36,000 feet for a 9-hour day. Reducing this gross daily output by the estimated 15 per cent defect yields 30,600 feet board measure as the net daily output.

Crew costs are as follows:

	Cost per hour
Tractor and driver (Table 19)	$3.77
Choker man (Table 16); average rate $4.15 per 8-hour day	.52
Swamper (Table 16); average rate $3.40 per 8-hour day	.42
Total	4.71

Crew cost for a 9-hour day thus equals $42.39. This cost divided by the net daily output of 30,600 feet board measure gives a net cost of skidding per thousand of $1.39.

ANALYSIS OF LOADING AND UNLOADING OUTPUT DATA

Graphs for loading and unloading output are summarized in Table 4. Figure 37 shows two curves representing sleigh-loading output per crew per hour in feet board measure, gross-scale, by log-per-thousand sizes, of two different crews—one a 5-man crew with horse jammer, the other a 4-man crew using a crosshaul. Figure 38 gives the output per crew per hour of loading auto trucks, and also the unloading output. In both Figures 37 and 38 the loading output is based on the actual loading time. Loading-output data in order to be of practical and permanent value must be based only upon actual loading time. The organization of the crew, the method of handling employed, and the type of loader used must be recorded with each set of data.

TABLE 4.—*Index to loading and unloading graphs and transportation other than skidding*

LOADING AND UNLOADING

Figure No.	Method	Organization and equipment	Size timber	Forest type	Slope	Labor	Season	Weather conditions
			Logs per thousand		*Per cent*			
37	Loading sleighs	Horse jammer; 5 men, crosshaul, 4 men.	3-22	Western white pine-larch-fir.		Day	Winter	
38	Loading and unloading autotrucks.	End horse-jammer loading, 5-man crew, 2 cant-hook men unloading.	2-20			do	Summer	

TRANSPORTATION

Figure No.	Method	Organization and equipment	Size timber	Forest type	Slope	Labor	Season	Weather conditions
39	Draying and skidding, horses	(1)	10	Ponderosa pine	0	Day	Winter	(1).
40	Dray haul	3 drays; loading crew, 3 men and teams.	3-12	Western white pine	0-15	do	do	Weather and snow conditions ideal.
41	Chute trailing, teams	Chutes; 3 to 9 teams depending on distance.	1-12	Ponderosa pine	0-10	do	Summer	Average.
42	do	do	6-25	do	0-15	do	Winter	Temperature below freezing; conditions ideal.
43	Chute trailing, tractors	Chute, 10-ton tractor	1-12	do	0-10	do	Summer	Average.
44	Sleigh haul	4 horses per sled; 4 and 5 sleds hauling.	10	Larch-Douglas fir	[2] 0-15	do	Winter	Weather and snow conditions ideal.
45	do	2 horses per sled; roads poorly constructed.	3-17	do	[2] 0-12	do	do	Temperature slightly below freezing; too warm for good sleighing.
46	Autotruck haul	5-ton truck; no trailer; plank road; 3 trucks hauling.	3-12	Western white pine	[2] 0-6	do	Summer	Average.
47	do	7½-ton truck, no trailer	9.5	Ponderosa pine	(3)	do	Winter	Good winter weather.
48	do	7½-ton truck, no trailer; road wet and soft.	3-17	do	0-6	do	Summer	

[1] See chart.
[2] Downhill.
[3] 5 per cent uphill for 600 feet then 0-15 per cent down.

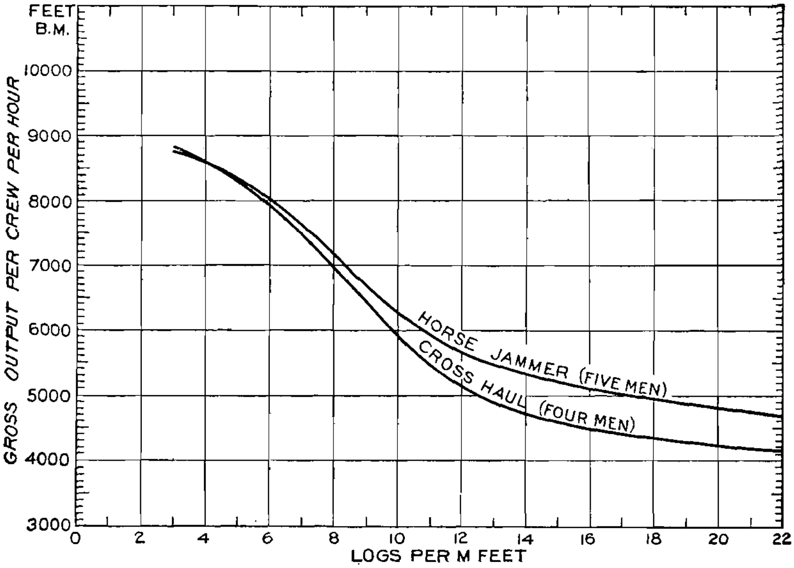

FIGURE 37.—Sleigh-loading output, with horse jammer and 5-man crew, and crosshaul and 4-man crew, both day labor. The curves represent output of actual loading time, including only such lost time as is incidental and properly chargeable to loading, putting the two methods on a comparative basis. Time lost in waiting for logs or sleds is not included but must be considered separately in accordance with the nature of any specific organization or job. Basis: Horse jammer, 222 M feet board measure, western white pine; crosshaul, 160 M feet board measure, larch-Douglas fir. Scale, Scribner decimal C. Data collected January–February, 1921

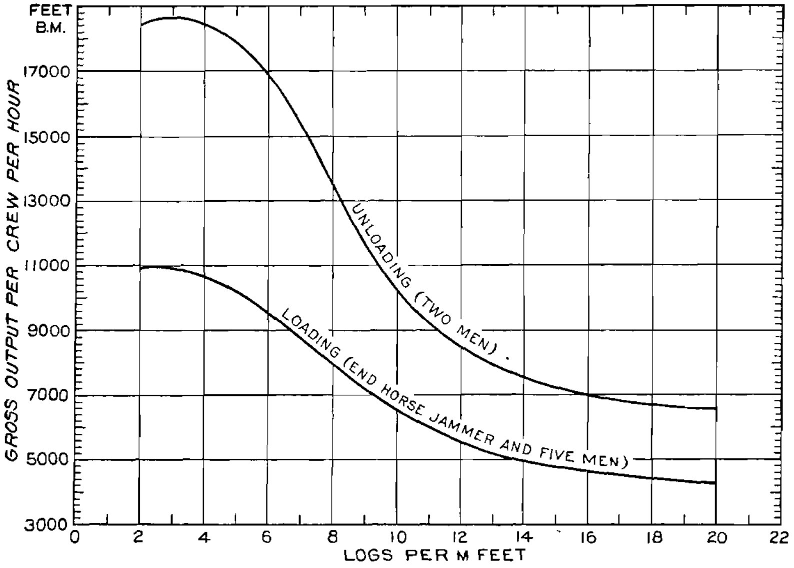

FIGURE 38.—Autotrucks loading and unloading output, with day labor. Loading-crew teams and teamster, top loader, 2 hookers, 1 taildown man; unloading crew, 2 canthook men. Only actual loading time and that lost which is properly chargeable to loading is included. Time lost waiting for logs or trucks is not included. Basis: 765 M feet board measure, 292 loads. Average per load, 2,620 feet board measure. Scale, Scribner decimal C. Data collected May, 1923

EFFECT OF VARIOUS FACTORS UPON OUTPUT

In the loading of logs upon sleighs, auto trucks, and railroad cars the organization of the crew, the method employed, and the equipment in use will largely determine the efficiency of the crew and are therefore of first importance. The location and character of the skidways in relation to the crosshaul, horse jammer, or power loader are important factors in increasing output. Any difference in output per unit of time as between two identical loading crews handling the same sized logs under the same conditions and methods and using the same type of loader will depend upon the time lost in waiting for logs or trucks or sleighs. The cost of loading in this region is perhaps affected more by such lost time than by any other factor. Maximum output per hour or per day can be obtained only by having available at all times enough logs to load and sufficient empty trucks or sleighs upon which to load them.

The output per effective hour based on actual loading time for a given loading crew will be influenced appreciably only by the size of the timber; length and form of the logs may, however, affect it slightly. A considerable percentage of very long or very short logs mixed with the usual run of 12, 14, and 16 foot logs will tend to lessen the output because of the greater difficulty of handling such logs. The same is true where the run includes a number of rough, knotty, much-tapered, or crooked logs.

Though it takes less time to load small logs than large ones, the output is not at all in proportion to the scale. That is, a log scaling 50 board feet can not be loaded in half the time that it takes to load a log containing 100 board feet. According to the loading curve in Figure 38, the approximate time necessary to load a 20-per thousand log is 43 seconds. The curve shows that it takes 55 seconds to load one 10-per-thousand log. This means that 1,000 feet board measure of the larger logs can be loaded in approximately two-thirds of the time required for the smaller logs.

The three loading curves in Figures 37 and 38 all clearly emphasize this effect of size of timber upon output. All three curves show a gradual increase in output from the smallest logs to the 12-log-per-thousand size group. Logs up to 12 per thousand may be classed as small. Where each log is loaded separately with hooks the output is necessarily low. This output may be increased by loading several logs together in looped chains. Beyond the 12-log-per-thousand size group, the output per crew per effective hour increases rapidly as the size of the timber increases, up to the largest logs. Medium to fairly large logs seem to be best suited for loading with horse jammer or crosshaul. The output increases more slowly as the timber increases in size from five logs per thousand. With power loaders, rapid increase in output would continue to a much larger log size.

The curves in Figure 37 compare the output obtained by two different-sized loading crews using different methods and equipment. The output obtained by the 4-man crew loading logs with a crosshaul averages 575 feet board measure less per effective hour for logs running between 22 and 12 logs per thousand than that obtained by the 5-man crew using a horse jammer. As the timber increases in size beyond the 12-log-per-thousand group the differ-

ence in output obtained by the two crews diminishes until 5-log-per-thousand timber is reached, where the output per crew is the same. It is evident from the curves that in loading logs smaller than five logs per thousand on sleighs, a greater output per effective hour based on actual loading time can be obtained from a 5-man crew with a horse jammer than from a 4-man crew loading with a crosshaul.

The loading output per effective hour for 4-man crews in 16, 10, and 5 log per thousand timber is, respectively, 4,500, 5,900, and 8,325 feet board measure, as compared with 5,100, 6,300, and 8,325 feet for 5-man crews. Just what factors or group of factors are responsible for this increased output by the 5-man crew in the smaller sizes of timber was not definitely determined by these studies. The additional man on the crew, the arrangement of the loading works, or the efficiency of the crew and loader may all influence the output. It is evident, however, that the size of the timber exerts a considerable influence on the output. If this were not so, an equal increase in output over that of the 4-man crew would be obtained by the 5-man crew, regardless of the size of the timber.

The output per effective hour of a 2-man crew unloading autotrucks (fig. 38) is influenced principally by such factors as size of timber, location of sleigh or truck landing in reference to pond, river, or yard into which the logs are to be unloaded, and the relation of actual unloading time to the time lost in waiting for loads to arrive. Proper facilities for unloading should be set up. The time lost by unloading crews in waiting for loaded trucks or sleds can be regulated by limiting the number of such crews until the time lost is negligible. The size of the timber will, therefore, exert the greatest influence upon output.

It will be noted that there is a very rapid increase in output as the size of the timber increases, particularly in the size groups between 10 and 5 logs per thousand. This shows that the larger and heavier the logs the easier it is to unload them. Once the key log of the load is set free by the cant-hook men, the remainder of the logs above the bottom tier usually roll off of their own weight, if the landings are properly constructed. Small logs which fit more tightly on the load often have to be rolled off singly. There is a limit, of course, to the size and weight of logs that can be handled advantageously by the unloading crew, especially if the heavy logs are loaded on the bottom of the truck or sled. This is shown by the fact that the output for 2-log-per-thousand timber dropped 200 feet board measure per crew per hour below that for logs running 3 logs per thousand.

HOW TO COMPUTE LOADING AND UNLOADING COSTS

The use of the output data to determine the cost per thousand of loading and unloading logs requires the following steps:

(1) Compute the average number of logs per thousand that are to be loaded or unloaded.

(2) Determine the gross output per hour for this computed size of timber from the graph which fits the specific operating conditions, methods, and equipment.

(3) Obtain the net output per hour of loading or unloading by reducing the above figure by the estimated percentage of defect.

(4) Find the net cost of loading or unloading per thousand by dividing the hourly cost of the loading or unloading crew by the net hourly output.

EXAMPLE A

Compare the cost per thousand of loading sleighs with a 4-man crew using a crosshaul and a 5-man crew using an end horse-jammer:

The timber runs 10 logs per thousand and is estimated to be 7 per cent defective. The job is so organized that there is practically no time lost in waiting for either logs or sleighs.

According to the horse-jammer curve of Figure 37, the gross output of 10-log timber per effective hour of a 5-man crew using the end horse-jammer is 6,300 feet board measure. The crosshaul curve shows the output per effective hour of the 4-man crew using a crosshaul to be 5,900 feet board measure gross scale. These figures are then reduced by 7 per cent for defects to 5,859 and 5,487 feet board measure net hourly output, respectively. Average hourly cost per unit 5-man crew (from Table 19) is $2.83. If this is divided by the net hourly output for the horse-jammer crew (5,859 feet) the result is 48 cents per thousand, the cost of loading. The hourly cost of a 4-man loading crew (one less cant-hook man than the 5-man crew) is $2.37, which divided by the net hourly output of 5,487 feet equals 43 cents per thousand, cost of loading.

EXAMPLE B

To find the cost per thousand of unloading autotrucks with a crew of two men employed on a day basis:

The timber runs 10 logs to the thousand and is 7 per cent defective. On the unloading curve (fig. 38) the gross output per crew per effective hour for 10-log timber is 10,250 feet, and the net hourly output (reduced for defect) is 9,532 feet board measure. Table 15 gives the average wage of a cant-hook man as $3.70 for an 8-hour day. The crew cost would be $7.40 a day or 92 cents an hour. This sum divided by the net hourly output equals 9.6 cents per thousand for unloading autotrucks.

ANALYSIS OF DATA FOR TRANSPORTATION OTHER THAN SKIDDING

In other methods of log transportation such as trailing in chutes, and dray, sleigh, and autotruck haul the general procedure is so similar both in obtaining and in applying the data that these methods can well be discussed together. The results of the studies are given in Figures 39 to 48.

Team and teamster constitute the unit crew for dray hauling and ordinarily for trailing in chutes with horses. In tractor trailing in chutes a 10-ton machine and a driver constitute a unit. The unit organization for sleigh hauling is a teamster and two or four horses. In autotruck hauling there is the driver with a truck of 5 or 7½ ton capacity. Details of organization are given on each graph. Output is based on logs-per-thousand groups, corresponding in prac-

tically all cases to the grouping used in skidding. The unit scale per load is also shown in most cases.

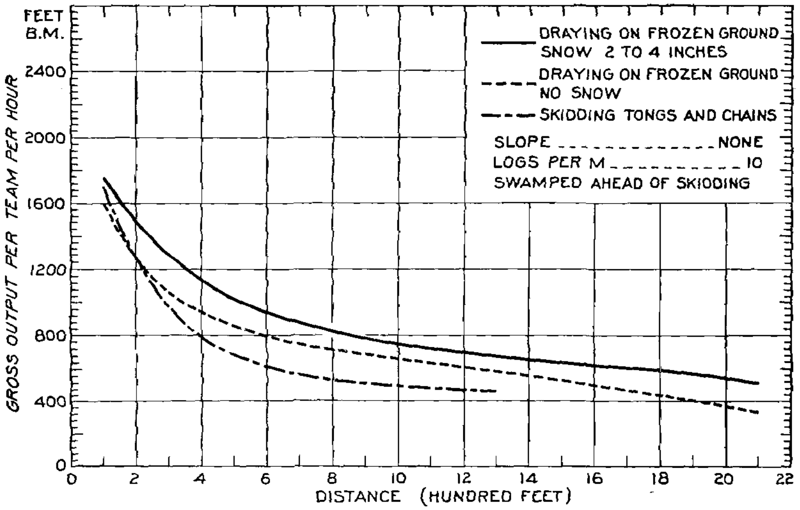

Figure 39.—Draying and skidding output in ponderosa pine type, winter work, day labor. Basis: 280 crew days, 1,530 M feet board measure

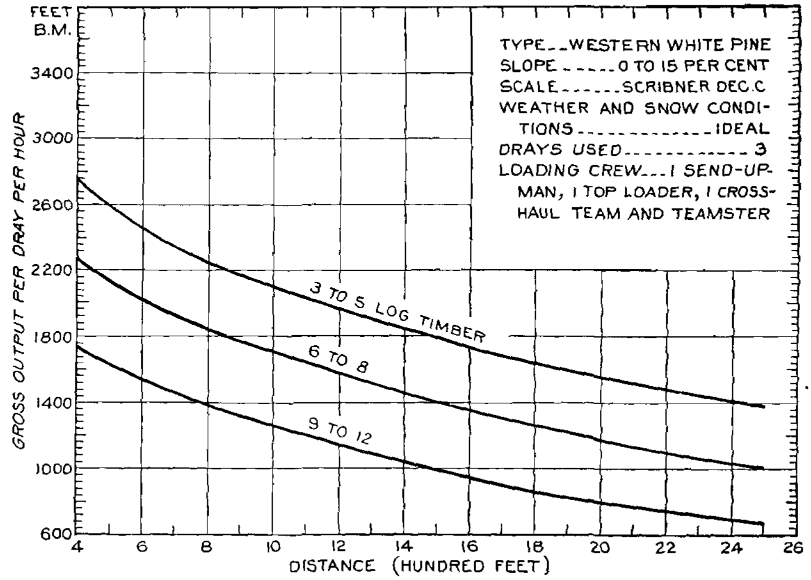

Figure 40.—Dray-haul output, in western white pine, winter work, day labor. Owing to ideal weather and snow, the output is greater than could be expected under average conditions. This output is identical with that obtained by a gyppo doing his own loading and tail-down work in a ponderosa pine type. All other conditions were similar. Basis: 840 M feet board measure, 1,103 trips. Data collected January–February, 1922

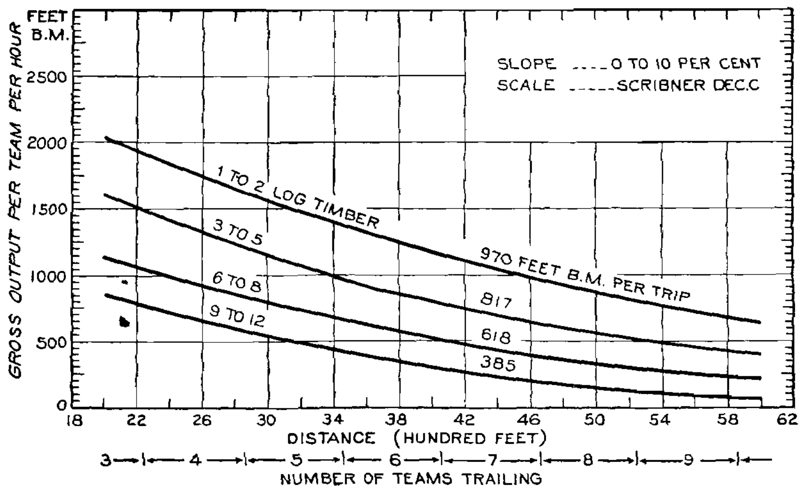

FIGURE 41.—Chute trailing output with teams, in ponderosa pine type. Summer work, day labor. Number of teams includes jig team. The chute was well constructed with easy curves. Basis: 146 M feet board measure, *186 trips*

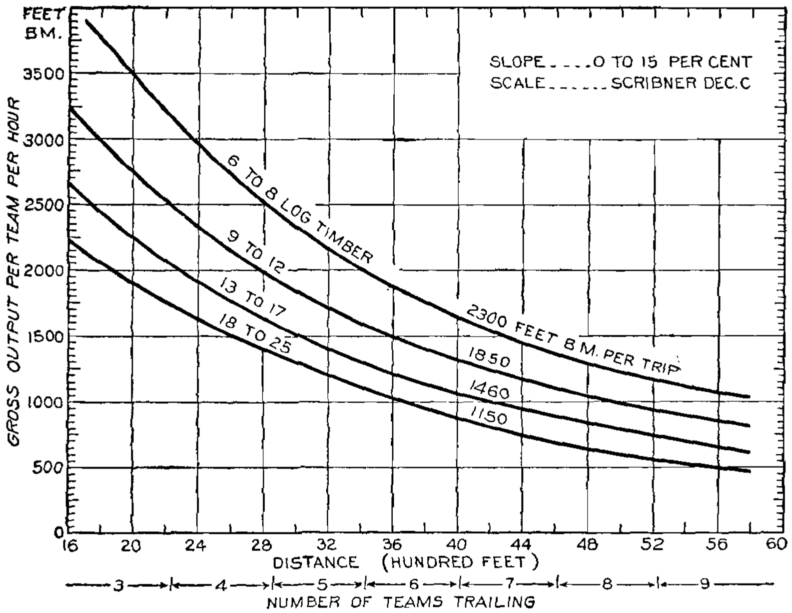

FIGURE 42.—*Chute-trailing output* with teams, in ponderosa pine type. Winter work. Day labor. Low temperature made chuting *conditions ideal. Basis:* 1,265 *feet* board measure, 705 trips. Data collected December, 1921

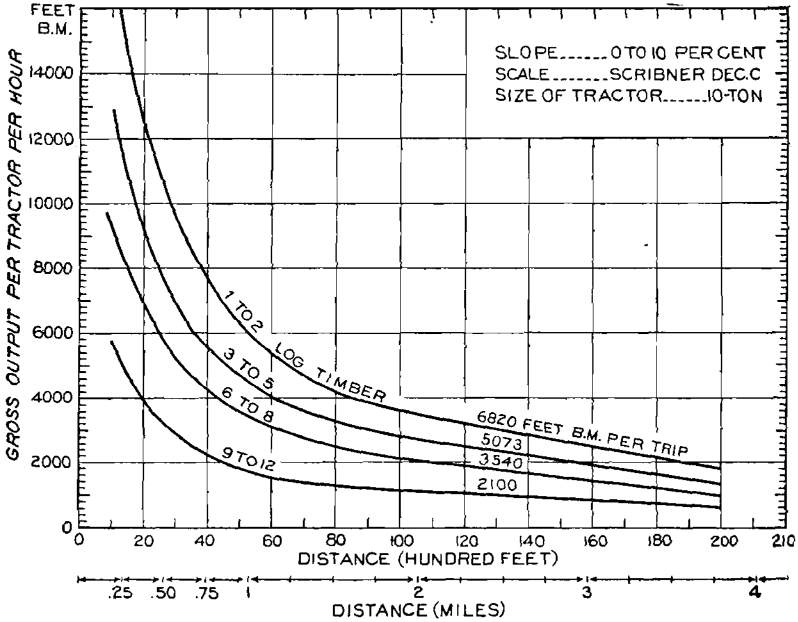

Figure 43.—Chute-trailing output with tractor, in ponderosa pine type. Summer work. Day labor. Chute was well constructed, with easy curves. Two teams making up trails at skidway and two discharging at landing. Only distance covered by tractor, exclusive of teams, included. Basis: 506 M feet board measure, 105 trips. Data collected June, 1923

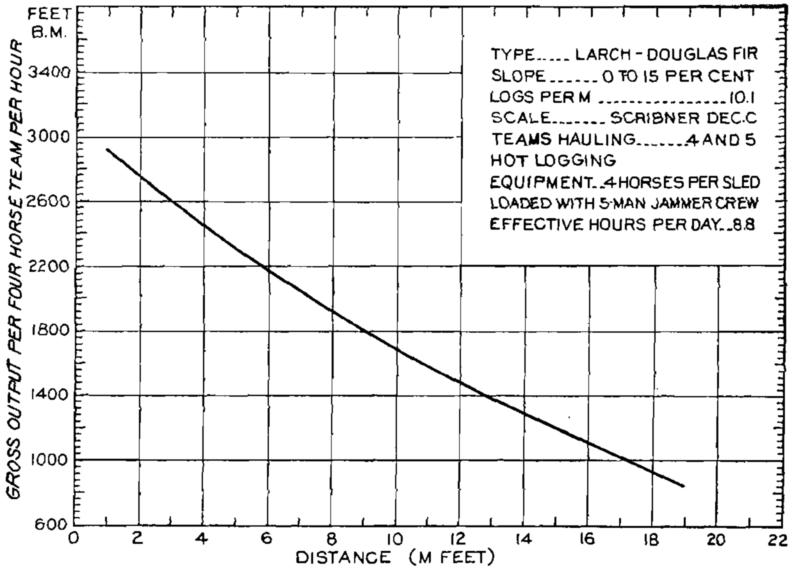

Figure 44.—Sleigh-haul output, with four horses per sled; weather and snow conditions very favorable, with temperature continually below freezing. Basis: 1,996 M feet board measure, 317 trips. Data collected January–February, 1922

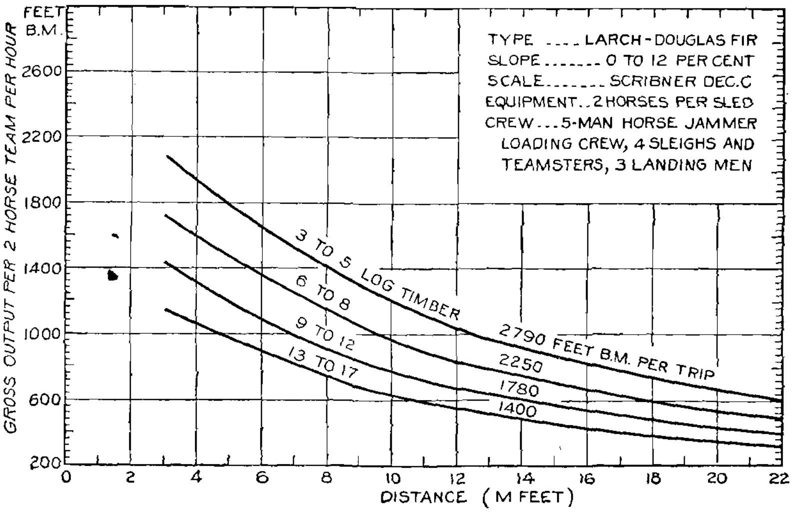

FIGURE 45.—Sleigh-haul output, with two horses per sled. Roads were poorly constructed, temperature slightly below freezing—too warm for good sleighing. Basis: 150 M feet board measure, 67 trips. Data collected January–February, 1921

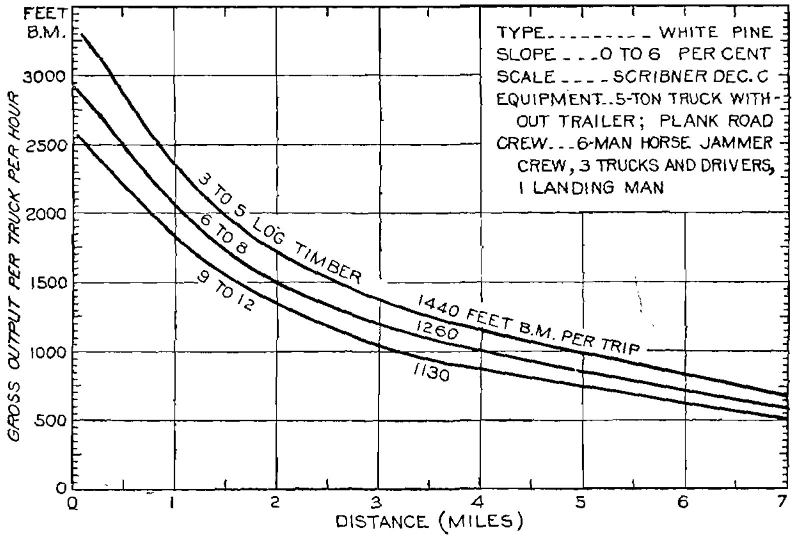

FIGURE 46.—Output for autotruck haul with 5-ton truck without trailer, plank road. Size of load limited to about 1,500 feet by condition of road. Basis: 104 M feet board measure, 549 logs, 88 trips. Data collected July, 1922

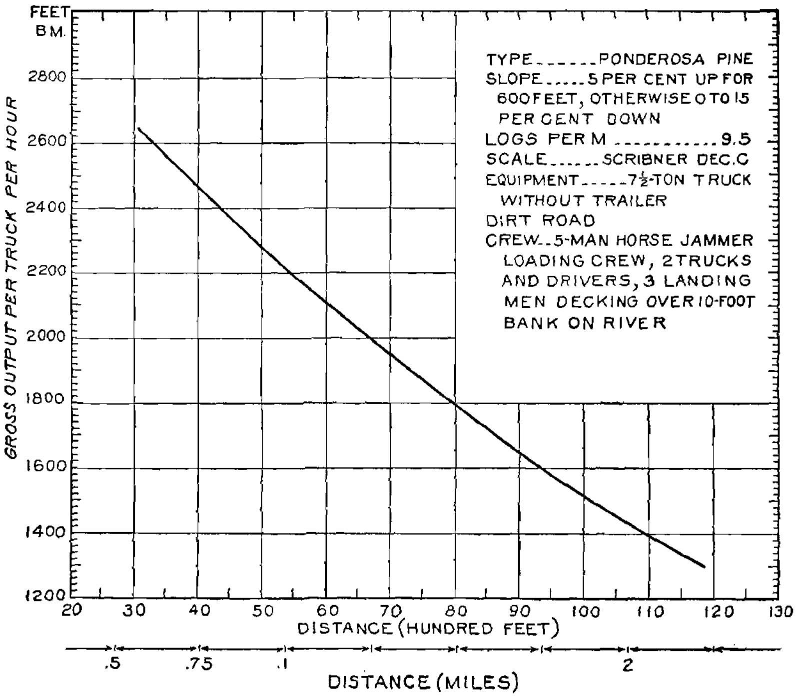

FIGURE 47.—Output for autotruck haul with 7½-ton truck without trailer, dirt road, winter work. Practically no grading or swamping required for roads. Temperature below freezing with ground frozen solid. Trucks average 3 miles per gallon of gasoline. Basis: 669 M feet board measure, 6,413 logs, 330 trips. Data collected January–February, 1922

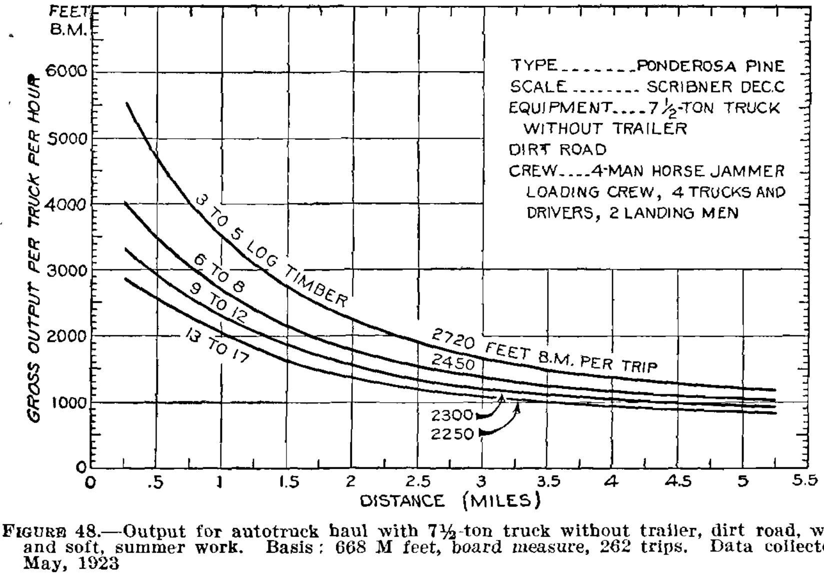

FIGURE 48.—Output for autotruck haul with 7½-ton truck without trailer, dirt road, wet and soft, summer work. Basis: 668 M feet, board measure, 262 trips. Data collected May, 1923

EFFECT OF NATURAL FACTORS UPON OUTPUT

The natural factors—size of timber, distance, slope, and operating seasons—which affect skidding output influence the output in all other methods of log transportation; and the basic facts or principles of logging brought out in the discussion of skidding apply likewise to trailing in chutes and hauling on drays, sleighs, and autotrucks.

The output obtained by trailing logs in chutes or hauling them on drays, autotrucks, or sleighs decreases rapidly as the size of the timber decreases. The following examples will be sufficient to show the effect of size on timber output:

The output per dray per hour obtained in hauling a distance of 1,000 feet is found (fig. 40) to be 2,100 feet board measure gross scale for 3 to 5 log per thousand timber, 1,700 feet board measure gross scale for 6 to 8 log per thousand timber, and 1,250 feet board measure gross scale for 9 to 12 log per thousand timber.

Trailing in chutes (fig. 43) registers an output per tractor per hour in trailing logs a distance of 1 mile as follows: 4,400 feet board measure gross scale in 3 to 5 log per thousand timber; 3,350 feet board measure gross scale in 6 to 8 log per thousand timber; and 1,750 feet board measure gross scale in 9 to 12 log per thousand timber.

The output per truck per hour obtained in trucking a distance of 4 miles is found (fig. 46) to be 1,150 feet board measure gross scale in 3 to 5 log per thousand timber; 1,000 feet board measure gross scale in 6 to 8 log per thousand timber; and 875 feet board measure gross scale in 9 to 12 log per thousand timber.

As in skidding, it is practically impossible, with the supporting and tractive power available, to haul or trail the same scale per load in small logs as in the very large timber. Often only just so many pieces, irrespective of size, can be handled on each load or in each trail. In order to obtain the same scale per load in the small 9 to 12 log per thousand timber as in the average load or trail of the larger 3 to 5 log size, it would be necessary, according to the data given in Figures 40, 43, and 46, to handle the following number of logs: Dray haul, 8 of the small logs to 3 of the larger logs; trailing in chutes with tractor, 53 of the small logs to 20 of the larger logs; and autotruck haul, nearly three times as many of the small logs as of the larger ones.

In hauling, bulk rather than weight is the limiting factor, and the limited capacity of the dray, autotruck, or sleigh would preclude the handling of enough small logs to equal the scale of larger logs that could be carried. However, as shown in the discussion of skidding, even if the capacity of the transporting equipment were ample to handle the increased number of small logs, a point would soon be reached where the greater weight of the smaller timber would be too great for the tractive power available. This would be particularly true in trailing logs in chutes with horses; ample room is available in any chute to handle a trail of logs of almost any length, but there is a limit to the weight of logs in the trail that the team can start. Even with tractor trailing, small logs are more costly to transport.

Log chutes are usually designed to handle the larger logs of the run. Small logs do not ride in the chute so well and are more apt to jump out, shove past the log in front, or buckle from pressure behind. For these reasons a trail composed of a number of small logs mixed with some very large ones, or of too many small logs, is difficult and costly to handle.

In hauling, distance also greatly increases the loss in output of small as compared with large timber. The gross output per hour for all sizes of timber decreases as the distance it must be transported increases; regardless of the scale per load, fewer trips are made per hour or per day. With fewer loads per day added to a lower scale per load, the decrease in output per hour for small timber is more rapid for each increase in distance than it is for large timber. As an example, the gross output per hour for 9 to 12 log timber dray hauled (fig. 40) a distance of 2,000 feet is less than half the output per hour that can be obtained when draying logs of the same size a distance of but 500 feet. In 3 to 5 logs per thousand timber the gross output per hour at 2,000 feet is 60 per cent of that at 500 feet.

Slope is an important factor in all transportation. The method and equipment to be used in transporting logs are dependent upon the percentage of slope. The slopes practicable for trailing in chutes and hauling with drays, autotrucks, and sleighs are gentler than those for skidding. Slope causes the greatest difference in output of various sizes of timber in draying and horse trailing, favoring large material at all distances. However, when a certain percentage of slope is reached the relation in output between different-sized timber remains practically constant. This point comes earliest in those methods, such as hauling by autotruck, where a definitely limited capacity makes tonnage a factor.

In certain types of transportation the season of the year and weather conditions are of particular importance. Though sleigh hauling demands a snow or ice surface, constant fluctuations in weather conditions result in a good deal of variation in output from day to day. Ideal weather and snow depth will allow a greater output in dray hauling than average conditions. Figures 41 and 42 illustrate effectively the output variation due to change in operating seasons and weather conditions. The trailing recorded in Figure 41 was done in summer; that in Figue 42 was done in January and February with the temperature continually below freezing, making chuting conditions ideal. In both cases the chutes were well constructed, and other conditions were practically the same. The output for summer chuting per team per hour in 6 to 8 log per thousand timber was 1,150 feet board measure gross scale trailed a distance of 2,000 feet, 800 feet board measure at 3,000 feet, 525 feet board measure at 4,000 feet, and 350 feet board measure for the 5,000-foot distance. Output per team per hour in winter chuting for the same size of timber and over the same distances reaches 3,500 feet board measure, 2,325 feet board measure, 1,650 feet board measure, and 1,225 feet board measure, respectively.

Where transportation is effected by wheeled vehicles, seasonal influences are generally negligible. In some cases the roadbed is improved in winter, in others it becomes more difficult.

HOW TO COMPUTE TRANSPORTATION COST

There is so little difference in the steps necessary in the specific application of the hauling data under the various methods of hauling that one set of instructions will suffice.

(1) Calculate the average draying, chuting, sleigh-haul, or autotruck-haul distance for the specific chance. In the examination of the logging area the method of minor log transportation will have been decided upon and the length and location of dray, sleigh, and autotruck roads and chutes tentatively determined.

(2) Compute the average number of logs per thousand.

(3) Determine the gross output per hour for the average distance hauled or chuted from the proper logs per thousand curve on the graph which fits the specific method under consideration. Reference to Table 4 will assist in this selection.

(4) Obtain gross daily output by multiplying the gross output per hour by the number of effective hours per day.

(5) Obtain the net daily output by reducing the above-mentioned figure by the estimated percentage of defect.

(6) Find the net cost of hauling or chuting per thousand feet by dividing the daily cost of the unit crew by the net daily output. Types of unit-cost records applicable to those branches of the operation are shown in Tables 14, 15, 16, and 21.

EXAMPLE A

To find the cost per thousand of dray hauling in the white pine type:

This chance (in the white pine type) is considered ideal for dray haul. Weather and snowfall in this particular district can usually be depended upon to afford good conditions for the use of drays. The slope is slight, averaging between 5 and 10 per cent. The average hauling distance is estimated at 1,000 feet. The logs will run 9 to 12 per thousand feet board measure. The timber is estimated as being 10 per cent defective. Eight effective hours on the job will constitute a day's work.

The cost is then estimated as follows:

The 9 to 12 log per thousand curve in Figure 40 shows the gross output per dray per hour for such timber hauled a distance of 1,000 feet to be 1,260 feet board measure. This makes the gross daily output 10,080 feet board measure, and the net daily output (10 per cent reduction) 9,072 feet board measure.

Average costs per unit crew are as follows:

Cost of team and teamster (Table 13) per effective day	$8.00
One-third of the average cost per effective day of woods-loading crew capable of loading three drays (top loader, $4.15; send-up man, $3.70; crosshaul team and teamster, $8)	5.28
Daily cost of unit crew	13.28

This amount divided by the net daily output gives $1.46 as the cost per thousand of dray haul.

EXAMPLE B

To find the cost per thousand of trailing ponderosa pine logs in a chute with teams:

Chuting is to be done in the summer, in well-constructed chutes with easy curves. The average distance over which logs must be

trailed in the chute is computed as 3,600 feet. The timber will run six to eight logs per thousand and is estimated at being 5 per cent defective. It is planned to have the men put in eight effective hours on the job.

The 6 to 8 log per thousand curve in Figure 41 gives the gross output per team per hour for 6 to 8 log timber trailed an average distance of 3,600 feet as 625 feet board measure. The graph shows that the number of teams used in trailing this distance would be six. This number includes the jig team. For the 8-hour day the gross daily output is then 5,000 feet board measure, and the net daily output (5 per cent reduction) 4,750 feet board measure.

Average costs per unit crew are as follows:

Cost of team and teamster (Table 13, 1929)	$7.30
One-fourth cost of jig team and teamster ($7.30 per day)	1.82
One-fifth cost of two men greasing chutes ($3.30 per day each)	1.32
Daily cost of unit crew	10.44

This amount divided by the net daily output=$2.20, the cost per thousand of trailing in chutes with teams, exclusive of the cost of chute grease.

EXAMPLE C

To find the cost per thousand of autotruck haul:

The distance is 3 miles over a good dirt road, the grade (6 per cent or less) being all downhill. Four 7½-ton trucks without trailers will be used on the job. It is estimated that a 5-man loading crew with a horse jammer will keep the four trucks going Two landing men will be needed. The timber is ponderosa pine running six to eight logs per thousand and 3½ per cent defective. Eight effective hours on the job will constitute a day's work.

The six to eight log per thousand curve in Figure 48 gives the daily output per truck per hour for a distance of 3 miles as 1,400 feet board measure, or 11,200 for an 8-hour day. The net daily output is then 10,808 feet. The unit cost per effective day of autotruck-haul crew, as given in Table 20, is $24.70. Dividing this by 10,808 feet board measure (net daily output) gives $2.29 as the cost per thousand autotruck haul.

ANALYSIS OF SWAMPING AND SLASH-DISPOSAL DATA

The output in swamping and slash disposal is much more difficult to classify than that in any other branch of logging work.

The brush itself can not be measured by methods that would be practicable in application. One thousand feet board measure of timber cut is used as the unit of measuring performance, but it does not express accurately the amount of brush handled. The quantity of brush or slash per thousand feet of timber cut varies greatly, not only among different species but even within the same species. This difference results from variations in undergrowth, stand density tree heights, and many other factors which can not be classified in output studies. Accordingly these phases of logging must be treated on a different and more general basis.

One man is taken as a unit in swamping and slash disposal, or in fact on any job in which each laborer works independently. In

contract horse skidding a working unit includes teamster and swamper, the teamster often assisting in swamping. Under day-work, swampers are not included in the crew, as swamping is usually done in advance of the skidding. Under present practice in tractor skidding one swamper may be included to work with the crew. Output and cost are influenced by the same factors in both slash disposal and swamping, and generally in the same manner.

The data contained in Table 5 were obtained from slash-disposal jobs in the white pine type of northern Idaho. Work in all cases was done during the summer season. The information on which the table is based is insufficient to justify more than very general conclusions. As previously indicated, this is probably all that could be expected from any amount of data on these operations.

EFFECT OF NATURAL FACTORS UPON OUTPUT

The natural factors which are chiefly instrumental in causing a wide variation in swamping and slash-disposal output are size and height of timber, stand per acre, composition of species, breakage, cull, and defect, utilization of tops, timber left uncut, and season of the year.

Size of timber undoubtedly is one of the more important single influences upon output in both jobs. Compare a 4-log tree, 18 inches in diameter, scaling 280 board feet, with a 6-log tree 40 inches in diameter which contains 2,800 board feet. The former has probably fully one-third as much slash in the top as the latter. This means that one-third as much work in limbing and slash disposal is charged against the 280 feet of volume in one case as is charged against ten times that volume in the second.

Height of timber is also an important factor. Tall timber has much less slash per thousand feet. The limbs are smaller and can be handled much more easily than the long limbs from short, scrubby timber.

Stand per acre affects both swamping and slash disposal, but not in the same manner. In a very heavy stand the cost per thousand of swamping may be greater than in a light stand, but usually that of slash disposal is less. The influence of stand per acre is brought out in Table 5, though rather indefinitely, by plot 2, where density is the only condition differing materially from those on the comparable plots. The large output of 1,390 board feet per hour on plot 2 is, in all probability, due to denseness of stand. A greater percentage of the brush must be handled by the swampers than in light stands. Often it is necessary to fell trees crosswise and on top of one another, which makes swamping more difficult than when all timber lies flat on the surface. On the other hand, there is less brush for disposal per thousand feet of timber cut, and a smaller percentage must be moved in piling. A larger proportion than usual must be piled by the swampers to clear the skid trails, a feature of the work that sometimes represents 60 to 80 per cent of the total cost of swamping. This would be the case in scattered stands of white pine where heavy windfall and dense clumps of hemlock and white fir saplings occur. In such stands slash-disposal costs would also be increased, but not to the same extent as swamping costs.

TABLE 5.—*Slash disposal output, western white pine type; summer season*[1]

PILING AND BURNING

Plot No.	Area	Density of windfall	Slope	Stand per acre	Western white pine			White fir and Douglas fir			Cedar—hemlock			Total volume	Time required	Output per effective hour
					Total volume	Size	Height	Total volume	Size	Height	Total volume	Size	Height			
	Acres		*Per cent*	*M ft.*	*M ft. b. m.*	*Logs per M*	*Logs per tree*	*M ft. b. m.*	*Logs per M*	*Logs per tree*	*M ft. b. m.*	*Logs per M*	*Logs per tree*	*M ft. b. m.*	*Hours*	*Ft. b. m.*
1	19.8	Light	45	31.6	433	14.0	4.3	186.0	8.7	4.1	7.0	15.0	3.5	626.0	690.0	907
2	13.2	Medium	45	40.9	276	13.0	4.4	246.0	8.2	4.4	18.0	12.3	3.2	540.0	388.5	1,390
3	10.5	do	45	25.9	162	10.2	5.0	95.0	8.1	5.4	15.3	12.0	3.3	272.3	225.0	1,210
4	38.3	Heavy	10	34.4	1,319	8.5	5.6							1,319.0	2,093.0	630
5	10.0	Medium	45	21.2	125	12.7	5.0	69.0	6.3	5.1	18.0	8.4	4.2	212.0	297.5	713
6	26.8	do	30	34.2	711	7.0	7.3	69.0	13.0	4.0	136.0	9.0	4.5	916.0	1,283.0	714

PROGRESSIVE BURNING

Plot No.	Area	Density of windfall	Slope	Stand per acre	Western white pine: Total volume	Western white pine: Size	Western white pine: Height	White fir and Douglas fir: Total volume	White fir and Douglas fir: Size	White fir and Douglas fir: Height	Cedar—hemlock: Total volume	Cedar—hemlock: Size	Cedar—hemlock: Height	Total volume	Time required	Output per effective hour
7	17.4	Medium	5	40.5	371	4.5	8.0	50.0	12.0	4.2	284.5	9.0	4.0	705.5	1,224.0	576
8	49.5	Light	5	36.7	1,201	5.5	8.0	87.1	13.0	4.0	530.1	9.0	5.0	1,818.2	4,350.0	418

[1] Density of undergrowth light on all plots.

Windfall has little effect on slash disposal except where windfall is so heavy that it becomes difficult to find clear spaces where the slash may be piled. This necessitates carrying the slash and accordingly reduces the output. This effect is illustrated by plot 4 in Table 5, where windfall was exceptionally heavy. The output of 630 board feet per effective hour on this plot is much lower than that on all other plots where slash was first piled and then burned (Nos. 1, 2, 3, 5, and 6), although other factors on this plot would tend to produce an average or above-average output.

Composition of stand has an important influence on the output or cost of swamping and slash disposal. Pure to almost pure stands of western white pine can be handled much more cheaply than stands containing considerable cedar, white fir, hemlock, and spruce. The same is true of a pure ponderosa pine type, as compared with ponderosa pine in mixture with considerable Douglas fir. Species such as hemlock, white fir, and Douglas fir, which are quite tolerant of shade and capable of good growth under their own shade and that of other species, do not prune their trunks of their lower branches but retain them in a green growing state throughout most of the life of the tree. Western white pine, on the other hand, can not endure much shade. Its shaded branches die off rapidly, and the tree usually cleans itself for a considerable distance above the ground. Outside of such generalities, it is impossible to determine definitely the effect that the various percentages of different species in the many different combinations that occur in this region may have on output.

Breakage occurs largely in the tops and therefore reduces the cost of swamping but increases that of slash disposal. Work which would otherwise have been done in swamping is added to the other operation. Cull and defect increase the cost per thousand of both swamping and slash disposal by reducing the net scale against which total cost is chargeable.

Poor utilization of tops has an effect similar to breakage. With close utilization swampers must trim more brush per thousand feet handled and slash-disposal men correspondingly less.

The quantity of timber left uncut is an important factor, but one which is difficult to classify or to appraise with regard to its effect on output. Standing trees often increase the cost per thousand feet of slash disposal for the timber removed. This cost, however, may still be much lower than where all species are cut to the smallest merchantable size. As an example, in a ponderosa pine type containing 30 per cent Douglas fir the cost per thousand feet of slash disposal is increased if the fir is left standing, since a considerable proportion of the Douglas fir limbs are knocked off in felling the pine. In order to protect from brush-burning fires the timber left standing after a selection cutting, the slash must be removed from around the bases of these trees and piled at a safe distance from them. This additional labor adds slightly to the cost of slash disposal.

Snow greatly increases the cost of swamping when it reaches a depth of more than 1 foot. The cost of slash disposal in the deep snow is prohibitive.

In Table 5 the output under two different methods of slash disposal has been compared. In the progressive method of disposal

(plots 7 and 8) the brush was burned as piled. In the other method (plots 1 to 6) the brush was first piled and later burned as a separate job. The table shows that under the progressive method the output is only about one-half that of the average for piling alone, in spite of the fact that the progressive method was employed in larger timber where output should be favored. For burning brush previously piled, the output per man averages about 10,000 per hour. Thus it may be seen that little change would occur in the present relative output between the two methods if the output for piling alone were to be reduced by the time spent later in burning the piles.

Steep slopes may become a handicap to the progressive method of slash disposal. The heat and smoke from the fire make piling in close from above very disagreeable. Day laborers in particular will carry the brush along the sidehills or place it on the fire from below rather than work from above. This, of course, increases the cost. In contrast to this, where piling and burning operations are carried on separately the bulk of the brush is thrown downhill without inconvenience to the worker. Progressive burning by contract crews is, however, often the cheapest and most satisfactory method of disposal. One great disadvantage is the shortness of the season in which the slash may be disposed of efficiently by progressive burning.

No further conclusions can be drawn with any degree of certainty. The data presented, however, indicate in a general way what may be accomplished in the white pine type under similar general conditions. They also serve as specific illustrations of some factors influencing output in swamping and slash disposal.

HOW TO COMPUTE SLASH-DISPOSAL COSTS

Use of the output data given in Table 5 is limited to the determination of the cost per thousand feet of slash disposal in the western (Idaho) white pine timber type. It will not be possible to select a plot that coincides in every respect with the specific operation to be studied, but the data presented will serve as a basis upon which to figure average costs. After selecting the plot which most closely approximates the area to be logged, note the output per man per effective hour, as given in board feet, gross log scale. This, multiplied by the number of effective working hours and reduced by the estimated percentage of defect, will give the net daily output. The cost per thousand feet is that found by dividing the labor cost by the net daily output.

The following example will illustrate the method of application.

EXAMPLE

To find the cost per thousand of slash disposal in a heavy western white pine stand:

The timber, which is 50 per cent western white pine, 45 per cent white fir and Douglas fir, and 5 per cent cedar and hemlock, runs 40,000 feet board measure to the acre. The white pine will run 13 logs per thousand, the white fir and Douglas fir 8 logs, and the cedar and hemlock 12 logs. The timber (all species) will average 5 per cent defective. The undergrowth is light, and there is only an average amount of windfall on the ground. Because of the slope,

which is approximately 45 per cent, the brush will first be piled and later burned. The brush-crew men will be expected to put in eight effective hours on the job.

Plot 2 most closely represents the conditions given. The output per man per effective hour is 1,390 board feet gross scale of brush piled, or 11,120 board feet in gross daily output. Reduction of 5 per cent for defect leaves 10,564 board feet net daily output. The cost per day of swamper or brush piler (Table 18) being $3.40, the cost per thousand of piling brush is $0.322.

For burning brush previously piled, the output per man per hour averages 10,000 feet. This is a good figure for this region. With the labor cost at $3.40 per day this comes to 4 cents per thousand. Total piling and burning cost is thus 36 cents per thousand.

APPLICATION OF OUTPUT DATA TO OPERATING PROBLEMS

Logging-output data can be used to great advantage both in planning and executing logging operations. Such data serve as a basis for a definite and accurate comparison of the relative advantages of the several methods of skidding and minor transportation, for an estimate of the effect of the location of minor improvements upon the cost of these methods, and for the consideration of other phases of the operation between the stump and the landing. Sound decisions on such points make possible the selection of the most economical and suitable system of major transportation. Too often the type of major transportation is considered and adopted without adequate consideration of its effect on the cost from stump to landing. When a detailed analysis of the whole problem has been made, certain characteristics of the area may warrant the adoption of minor improvements and certain methods of sawing and skidding which in themselves are so economical as to justify a means of primary transportation that would otherwise appear unwarranted. Such use of output data could be discussed at great length but can probably best be emphasized by illustrations of the actual application of the data to specific operating problems.

Tables 6 and 7 afford a comparison between skidding with horses and 10-ton track-laying tractors in the ponderosa pine type. There is shown the proper spacing of improvements and the most feasible methods of skidding for different stand, slope, weather, and construction-cost conditions. In all, 16 different operating and stand conditions are covered. For each condition a comparative combined cost per thousand feet of railroad construction and skidding by horses and by tractor is given for the range of distances ordinarily encountered. Beginning with the 0 to 15 per cent slope classification, output and cost are shown for two separate log groups, with two different stand volumes and under both summer and winter conditions. The same comparisons are then presented for a slope classification of 15 to 30 per cent. Similar comparisons may be made from the output charts for many other operating problems upon different slopes, for different sizes of timber, etc., whenever doubt exists as to the most feasible operating method. From such data it is not difficult to determine the most economical methods or combination of methods.

TABLE 6.—*A comparison of skidding with horses and track-laying tractors, on 0 to 15 per cent slopes, with railroad cost of $2,000 per mile.*

SUMMER SEASON

Average actual skidding distance (feet) [1]	Railroad cost, by stand per acre [2]		Skidding with track-laying tractor [3]								Skidding with horses [3]							
			3 to 5 logs per M		9 to 12 logs per M		Cost including railroad construction [4]				3 to 5 logs per M		9 to 12 logs per M		Cost including railroad construction [4]			
							3 to 5 logs per M		9 to 12 logs per M						3 to 5 logs per M		9 to 12 logs per M	
	10 M	20 M	Output	Cost per M	Output	Cost per M	10 M	20 M	10 M	20 M	Output	Cost per M	Output	Cost per M	10 M	20 M	10 M	20 M
	Dollars	*Dollars*	*Ft. b. m.*	*Dollars*	*Ft. b. m.*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Ft. b. m.*	*Dollars*	*Ft. b. m.*	*Dollars*	*Dollars*	*Dollars*	*Dollars*	*Dollars*
60	8.25	4.12	10,700	0.54	6,100	0.94	8.79	4.66	9.19	5.06	2,990	0.40	1,630	0.74	8.65	4.52	8.99	4.86
120	4.12	2.06	10,450	.55	5,880	.97	4.67	2.61	5.09	3.03	2,685	.45	1,485	.81	4.57	2.51	4.93	2.87
180	2.75	1.38	10,100	.57	5,680	1.01	3.32	1.95	3.76	2.39	2,320	.52	1,335	.91	3.27	1.90	3.66	2.29
240	2.06	1.03	9,730	.59	5,550	1.04	2.65	1.62	3.10	2.07	1,990	.61	1,195	1.01	2.67	1.64	3.07	2.04
300	1.65	.82	9,350	.61	5,300	1.08	2.26	1.43	2.73	1.90	1,735	.70	1,075	1.13	2.35	1.52	2.78	1.95
360	1.38	.69	8,950	.64	5,100	1.12	2.02	1.33	2.50	1.81	1,520	.80	965	1.25	2.18	1.49	2.63	1.94
420	1.18	.59	8,560	.67	4,900	1.17	1.85	1.26	2.35	1.76	1,340	.90	870	1.39	2.08	1.49	2.57	1.98
480	1.03	.52	8,150	.70	4,740	1.21	1.73	1.22	2.24	1.73	1,200	1.01	790	1.53	2.04	1.53	2.56	2.05
540	.92	.46	7,770	.74	4,570	1.25	1.66	1.20	2.17	1.71	1,090	1.11	725	1.67	2.03	1.57	2.59	2.13
600	.82	.41	7,400	.77	4,400	1.30	1.59	1.18	2.12	1.71	1,010	1.20	670	1.81	2.02	1.61	2.63	2.22
660	.75	.38	7,060	.81	4,220	1.36	1.56	1.19	2.11	1.74	940	1.29	620	1.95	2.04	1.67	2.70	2.33
720	.69	.34	6,720	.85	4,080	1.40	1.54	1.19	2.09	1.74	880	1.37	575	2.10	2.06	1.71	2.79	2.44
780	.63	.32	6,400	.90	3,900	1.47	1.53	1.22	2.10	1.79	825	1.47	540	2.24	2.10	1.79	2.87	2.56
840	.59	.30	6,130	.93	3,770	1.52	1.52	1.23	2.11	1.82	780	1.55	510	2.37	2.14	1.85	2.96	2.67
900	.55	.28	5,890	.97	3,610	1.59	1.52	1.25	2.14	1.87	735	1.65	480	2.52	2.20	1.93	3.07	2.80
960	.52	.26	5,630	1.02	3,500	1.64	1.54	1.28	2.16	1.90	700	1.73	450	2.69	2.25	1.99	3.21	2.95
1,020	.48	.24	5,400	1.06	3,370	1.70	1.55	1.30	2.18	1.94	665	1.82	430	2.81	2.30	2.06	3.29	3.05
1,080	.46	.23	5,200	1.10	3,240	1.77	1.56	1.33	2.23	2.00	630	1.92	410	2.95	2.38	2.15	3.41	3.18
1,140	.43	.22	5,030	1.14	3,140	1.82	1.57	1.36	2.25	2.04	600	2.02	390	3.10	2.45	2.24	3.53	3.32
1,200	.41	.20	4,870	1.18	3,040	1.89	1.59	1.38	2.30	2.09	575	2.10	370	3.27	2.51	2.30	3.68	3.47

WINTER SEASON

60	8.25	4.12	9,740	0.59	5,900	0.97	8.84	4.71	9.22	5.09	3,565	0.34	1,695	0.71	8.59	4.46	8.96	4.83
120	4.12	2.06	9,400	.61	5,650	1.01	4.73	2.67	5.13	3.07	3,040	.40	1,525	.79	4.52	2.46	4.91	2.85
180	2.75	1.38	9,090	.63	5,400	1.06	3.38	2.01	3.81	2.44	2,435	.50	1,370	.88	3.25	1.88	3.63	2.26
240	2.06	1.03	8,780	.65	5,200	1.10	2.71	1.68	3.16	2.13	2,030	.60	1,225	.99	2.66	1.63	3.05	2.02
300	1.65	.82	8,420	.68	5,000	1.15	2.33	1.50	2.80	1.97	1,750	.69	1,100	1.10	2.34	1.51	2.75	1.92
360	1.38	.69	8,100	.71	4,820	1.19	2.09	1.40	2.57	1.88	1,540	.79	995	1.22	2.17	1.48	2.60	*1.91*
420	1.18	.59	7,800	.73	4,660	1.23	1.91	1.32	2.41	1.82	1,395	.87	900	1.34	2.05	*1.46*	2.52	1.93
480	1.03	.52	7,520	.76	4,500	1.27	1.79	1.28	2.30	1.79	1,280	.95	815	1.48	1.98	1.47	*2.51*	2.00
540	.92	.46	7,250	.79	4,380	1.31	1.71	1.25	2.23	1.77	1,195	1.01	750	1.61	1.93	1.47	2.53	2.07
600	.82	.41	7,000	.82	4,250	1.35	1.64	1.23	2.17	*1.76*	1,125	1.08	700	1.73	1.90	1.49	2.55	2.14
660	.75	.38	6,760	.85	4,120	1.39	1.60	1.23	2.14	1.77	1,070	1.13	650	1.86	*1.88*	1.51	2.61	2.24
720	.69	.34	6,540	.88	4,010	1.43	1.57	*1.22*	2.12	1.77	1,015	1.19	620	1.95	1.88	1.53	2.64	2.29
780	.63	.32	6,320	.91	3,900	1.47	1.54	1.23	2.10	1.79	970	1.25	590	2.05	1.88	1.57	2.68	2.37
840	.59	.30	6,140	.93	3,800	1.51	1.52	1.23	2.10	1.81	935	1.29	560	2.16	1.88	1.59	2.75	2.46
900	.55	.28	5,980	.96	3,710	1.54	1.51	1.24	*2.09*	1.82	900	1.34	540	2.24	1.89	1.62	2.79	2.52
960	.52	.26	5,800	.99	3,620	1.58	1.51	1.25	2.10	1.84	870	1.39	525	2.30	1.91	1.65	2.82	2.56
1,020	.49	.24	5,650	1.01	3,550	1.61	*1.49*	1.25	2.09	1.85	845	1.43	510	2.37	1.91	1.67	2.86	2.61
1,080	.46	.23	5,520	1.04	3,480	1.65	1.50	1.27	2.11	1.88	820	1.48	495	2.44	1.94	1.71	2.90	2.67
1,140	.43	.22	5,400	1.06	3,400	1.69	1.49	1.28	2.12	1.91	795	1.52	480	2.52	1.95	1.74	2.95	2.74
1,200	.41	.20	5,280	1.09	3,320	1.73	1.50	1.29	2.14	1.93	775	1.56	470	2.58	1.97	1.76	2.99	2.78

[1] Average actual skidding distance is half the maximum actual distance, or 60 per cent of the maximum direct distance from stump to railroad.

[2] Twice maximum direct skidding distance is taken as distance between spurs since skidding on these slopes will be from both sides of spur. Costs vary directly with area served and stand per acre.

[3] Output (taken from figs. 18, 21, 27, and 29) is per hour at average skidding distance (60 per cent of maximum direct) and costs are per thousand feet board measure. Cost is figured by dividing crew cost by output per effective hour for each distance. Crew costs are figured from cost tables given in appendix.

[4] Figures in italic indicate the actual skidding distance at which all factors combine to produce the lowest total cost.

TABLE 7.—*A comparison of skidding with horses and track-laying tractors, on 15 to 30 per cent slopes, with railroad cost of $3,000 per mile*

SUMMER SEASON

Average actual skidding distance (feet) [1]	Railroad cost by stand per acre [2]		Skidding with track-laying tractor [3]								Skidding with horses [3]							
			3 to 5 logs per M		9 to 12 logs per M		Cost including railroad construction [4]				3 to 5 logs per M		9 to 12 logs per M		Cost including railroad construction [4]			
							3 to 5 logs per M		9 to 12 logs per M						3 to 5 logs per M		9 to 12 logs per M	
	10 M	20 M	Output	Cost per M	Output	Cost per M	10 M	20 M	10 M	20 M	Output	Cost per M	Output	Cost per M	10 M	20 M	10 M	20 M
60	24.75	12.38	13,400	0.43	6,300	0.91	25.18	12.81	25.66	13.29	3,770	0.32	1,965	0.62	25.07	12.70	25.37	13.00
120	12.38	6.19	13,000	.44	6,080	.94	12.82	6.63	13.32	7.13	3,375	.36	1,740	.70	12.74	6.55	13.08	6.89
180	8.25	4.12	12,640	.45	5,850	.98	8.70	4.57	9.23	5.10	2,975	.41	1,535	.79	8.66	4.53	9.04	4.91
240	6.19	3.10	12,240	.47	5,620	1.02	6.66	3.57	7.21	4.12	2,620	.46	1,355	.89	6.65	3.56	7.08	3.99
300	4.95	2.48	11,800	.49	5,400	1.06	5.44	2.97	6.01	3.54	2,310	.52	1,200	1.01	5.47	3.00	5.96	3.49
360	4.12	2.06	11,350	.50	5,200	1.10	4.62	2.56	5.22	3.16	2,050	.59	1,060	1.14	4.71	2.65	5.26	3.20
420	3.54	1.77	10,860	.53	5,000	1.15	4.07	2.30	4.69	2.92	1,830	.66	950	1.27	4.20	2.43	4.81	3.04
480	3.09	1.54	10,300	.56	4,800	1.19	3.65	2.10	4.28	2.73	1,645	.74	860	1.41	3.83	2.28	4.50	2.95
540	2.75	1.38	9,600	.60	4,620	1.24	3.35	1.98	3.99	2.62	1,480	.82	780	1.55	3.57	2.20	4.30	2.93
600	2.48	1.24	9,300	.62	4,460	1.28	3.10	1.86	3.76	2.52	1,350	.90	720	1.68	3.38	2.14	4.16	2.92
660	2.25	1.12	8,880	.65	4,300	1.33	2.90	1.77	3.58	2.45	1,240	.98	660	1.83	3.23	2.10	4.08	2.95
720	2.06	1.03	8,450	.68	4,140	1.38	2.74	1.71	3.44	2.41	1,150	1.05	620	1.95	3.11	2.08	4.01	2.98
780	1.90	.95	8,040	.71	4,000	1.43	2.61	1.66	3.33	2.38	1,065	1.14	575	2.10	3.04	2.09	4.00	3.05
840	1.77	.88	7,680	.75	3,860	1.48	2.52	1.63	3.25	2.36	995	1.22	545	2.22	2.99	2.10	3.99	3.10
900	1.65	.82	7,340	.78	3,740	1.53	2.43	1.60	3.18	2.35	930	1.30	520	2.33	2.95	2.12	3.98	3.15
960	1.55	.78	7,000	.82	3,610	1.59	2.37	1.60	3.14	2.37	875	1.38	495	2.44	2.93	2.16	3.99	3.22
1,020	1.46	.73	6,700	.86	3,520	1.63	2.32	1.59	3.09	2.36	830	1.46	475	2.55	2.92	2.19	4.01	3.28
1,080	1.38	.69	6,480	.88	3,420	1.68	2.26	1.57	3.06	2.37	785	1.54	455	2.66	2.92	2.23	4.04	3.35
1,140	1.30	.65	6,220	.92	3,360	1.71	2.22	1.57	3.01	2.36	755	1.60	440	2.75	2.90	2.25	4.05	3.40
1,200	1.24	.62	6,020	.95	3,280	1.75	2.19	1.57	2.99	2.37	730	1.66	425	2.85	2.90	2.28	4.09	3.47
1,260	1.18	.59	5,840	.98	3,200	1.79	2.16	1.57	2.97	2.38								
1,320	1.12	.56	5,680	1.01	3,140	1.82	2.13	1.57	2.94	2.38								
1,380	1.08	.54	5,510	1.04	3,080	1.86	2.12	1.58	2.94	2.40								
1,440	1.03	.52	5,380	1.07	3,010	1.90	2.10	1.59	2.93	2.42								
1,500	.99	.50	5,220	1.10	2,960	1.94	2.09	1.60	2.93	2.44								
1,560	.95	.48	5,100	1.12			2.07	1.60										
1,620	.92	.46	4,960	1.16			2.08	1.62										
1,680	.88	.44	4,860	1.18			2.06	1.62										
1,740	.85	.42	4,760	1.20			2.05	1.62										

WINTER SEASON

60	24.75	12.38	13,500	0.42	5,400	1.06	25.17	12.80	25.81	13.44	3,300	0.37	1,690	0.72	25.12	12.75	25.47	13.10
120	12.38	6.19	12,980	.44	5,200	1.10	12.82	6.63	13.48	7.29	3,110	.39	1,550	.78	12.77	6.58	13.16	6.97
180	8.25	4.12	12,480	.46	5,020	1.14	8.71	4.58	9.39	5.26	2,930	.41	1,410	.86	8.66	4.53	9.11	4.98
240	6.19	3.10	12,000	.48	4,850	1.18	6.67	3.58	7.37	4.28	2,750	.44	1,275	.95	6.63	3.54	7.14	4.05
300	4.95	2.48	11,550	.50	4,680	1.22	5.45	2.98	6.17	3.70	2,580	.47	1,155	1.05	5.42	2.95	6.00	3.53
360	4.12	2.06	11,140	.51	4,500	1.27	4.63	2.57	5.39	3.33	2,410	.50	1,050	1.15	4.62	2.56	5.27	3.21
420	3.54	1.77	10,740	.53	4,310	1.33	4.07	2.30	4.87	3.10	2,240	.54	950	1.27	4.08	2.31	4.81	3.04
480	3.09	1.54	10,360	.55	4,150	1.38	3.64	2.09	4.47	2.92	2,075	.58	875	1.38	3.67	2.12	4.47	2.92
540	2.75	1.38	9,960	.58	3,990	1.44	3.33	1.96	4.19	2.82	1,920	.63	800	1.51	3.38	2.01	4.26	2.89
600	2.48	1.24	9,600	.60	3,840	1.49	3.08	1.84	3.97	2.73	1,775	.68	750	1.61	3.16	1.92	4.09	*2.85*
660	2.25	1.12	9,240	.62	3,680	1.56	2.87	1.74	3.81	2.68	1,640	.74	700	1.73	2.99	1.86	3.98	2.85
720	2.06	1.03	8,880	.65	3,540	1.62	2.71	1.68	3.68	2.65	1,520	.80	665	1.82	2.86	1.83	3.88	2.85
780	1.90	.95	8,520	.67	3,400	1.69	2.57	1.62	3.59	*2.64*	1,410	.86	630	1.92	2.76	1.81	3.82	2.87
840	1.77	.88	8,200	.70	3,250	1.76	2.47	1.58	3.53	2.64	1,315	.92	605	2.00	2.69	*1.80*	3.77	2.88
900	1.65	.82	7,880	.73	3,150	1.82	2.38	1.55	3.47	2.64	1,230	.98	585	2.07	2.63	1.80	3.72	2.89
960	1.55	.78	7,580	.76	3,050	1.88	2.31	1.54	3.43	2.66	1,160	1.04	570	2.12	2.59	1.82	3.67	2.90
1,020	1.46	.73	7,300	.78	2,960	1.94	2.24	1.51	3.40	2.67	1,100	1.10	555	2.18	2.56	1.83	3.64	2.91
1,080	1.38	.69	7,020	.82	2,880	1.99	2.20	1.51	3.37	2.68	1,050	1.15	540	2.24	2.53	1.84	3.62	2.93
1,140	1.30	.65	6,760	.85	2,800	2.05	2.15	*1.50*	3.35	2.70	1,000	1.21	525	2.30	2.51	1.86	3.60	2.95
1,200	1.24	.62	6,500	.88	2,720	2.11	2.12	1.50	3.35	2.73	960	1.26	515	2.35	2.50	1.88	3.59	2.97
1,260	1.18	.59	6,280	.91	2,660	2.15	2.09	1.50	3.33	2.74	930	1.30	500	2.42	2.48	1.89	3.60	3.01
1,320	1.12	.56	6,060	.95	2,600	2.20	2.07	1.51	3.32	2.76	900	1.34	490	2.47	2.46	1.90	*3.59*	3.03
1,380	1.08	.54	5,860	.98	2,550	2.25	2.06	1.52	3.33	2.79	875	1.38	480	2.52	2.46	1.92	3.60	3.06
1,440	1.03	.52	5,700	1.01	2,500	2.29	2.04	1.53	3.32	2.81	850	1.42	470	2.57	2.45	1.94	3.60	3.09
1,500	.99	.50	5,540	1.03	2,460	2.33	2.02	1.53	3.32	2.83	835	1.45			2.44	1.95		
1,560	.95	.48	5,400	1.06	2,420	2.37	2.01	1.54	3.32	2.85	815	1.48			*2.43*	1.96		
1,620	.92	.46	5,300	1.08	2,390	2.40	2.00	1.54	3.32	2.86	795	1.52			2.44	1.98		
1,680	.88	.44	5,180	1.11	2,370	2.42	1.99	1.55	3.30	2.86	775	1.56			2.44	2.00		
1,740	.85	.42	5,090	1.13	2,340	2.45	1.98	1.55	3.30	2.87	755	1.60			2.45	2.02		
1,800	.82	.41	5,000	1.15	2,310	2.48	*1.97*	1.56	*3.30*	2.89	740	1.64			2.46	2.05		

[1] Average actual skidding distance is half the maximum actual distance, or 60 per cent of the maximum direct distance from stump to railroad.

[2] Maximum direct skidding distance is taken as distance between spurs since on these slopes skidding is from one side of slope only. Costs vary directly with area served and stand per acre.

[3] Output (taken from figs. 19, 22, 28 and 30) is per hour at average skidding distance (60 per cent of maximum direct) and costs per thousand feet board measure. Cost is figured by dividing crew cost by output per effective hour for each distance. Crew costs are figured from cost tables given in appendix.

[4] Figures in italic indicate the actual skidding distance at which all factors combine to produce the lowest total cost.

Output or costs for swamping, skidway construction, and tailing down on skidways have not been included in these tables. These operations, if properly organized, do not materially affect the cost of skidding and accordingly do not influence the proper spacing of the railroad spurs or transportation routes. The comparisons assume, as is ordinarily the case, that timber skidded by tractor is felled downhill, limbed, topped, and skidded in tree lengths, whereas that skidded by horses is in logs averaging about 16 feet.

The points of chief interest brought out in the preceding tables are shown in condensed form in Tables 8 and 9. In Table 8 is given, for the various slopes, seasons, and timber sizes, the point at which, and the width of strip or zone within which, the timber may be skidded by either horse or tractor at approximately the same cost.

TABLE 8.—*Point and zone of equivalent cost as between tractor and horse skidding, under various operating conditions*

Operating conditions	Point of equal cost [1]	Zone of equal cost	Cost per M [2]
0 to 15 per cent slope:			
Summer work—	*Feet*	*Feet*	*Dollars*
3 to 5 log timber	210	350	0.56
9 to 12 log timber	270	450	1.07
Winter work—			
3 to 5 log timber	270	450	.64
9 to 12 log timber	330	550	1.16
15 to 30 per cent slope:			
Summer work—			
3 to 5 log timber	270	450	.49
9 to 12 log timber	330	550	1.08
Winter work—			
3 to 5 log timber	390	650	.52
9 to 12 log timber	480	800	1.38

[1] Beyond distances given, tractor skidding is more economical; short of these distances horse skidding has the advantage.
[2] Cost at point of equivalence or average cost for zone.

TABLE 9.—*Most economical distances between railroad spurs and the most economical direct-skidding distances; and the combined cost per thousand of railroad construction and skidding*

Operating conditions	Stand per acre	Tractor skidding: Distance between railroad spurs [1]	Tractor skidding: Combined cost	Horse skidding: Distance between railroad spurs [1]	Horse skidding: Combined cost
0 to 15 per cent slope:					
Summer work—	*M ft. b. m.*	*Feet*	*Dollars*	*Feet*	*Dollars*
3 to 5 log timber	10	2,800	1.52	2,000	2.02
	20	2,000	1.18	1,200	1.49
9 to 12 log timber	10	2,400	2.09	1,600	2.56
	20	1,800	1.71	1,200	1.94
Winter work—					
3 to 5 log timber	10	3,400	1.50	2,200	1.88
	20	2,400	1.22	1,400	1.46
9 to 12 log timber	10	3,000	2.09	1,600	2.51
	20	2,000	1.76	1,200	1.91
15 to 30 per cent slope:					
Summer work—					
3 to 5 log timber	10	5,800	2.05	4,000	2.90
	20	3,600	1.57	2,400	2.08
9 to 12 log timber	10	5,000	2.93	3,000	3.98
	20	3,000	2.35	2,000	2.92
Winter work—					
3 to 5 log timber	10	6,000	1.97	5,200	2.43
	20	3,800	1.50	2,800	1.80
9 to 12 log timber	10	6,000	3.30	4,400	3.59
	20	2,600	2.64	2,000	2.85

[1] Twice the maximum direct distance.

The figures in Table 8 illustrate again the effect of slope, season, and size of timber upon the relative efficiency of tree-skidding methods. Slopes of 15 to 30 per cent, winter work, and small timber tend to favor the horses. In other words, the point of equal cost for skidding with horses and tractors will be advanced as slope increases, timber becomes smaller, or weather conditions change from summer to winter.

As an example, Table 8 shows that 3 to 5 log timber can be skidded in summer over 0 to 15 per cent slopes for a distance of 210 feet at the same cost per thousand for horses and tractor. For shorter distances, skidding with horses is cheaper, and for greater distances skidding with tractors is cheaper. On the same slope, under winter conditions, the distance at which the cost is approximately identical increases from 210 to 270 feet for 3 to 5 log timber and from 270 to 330 feet for 9 to 12 log timber. On steeper slopes (15 to 30 per cent) 9 to 12 log timber can, under winter conditions, be skidded a distance of 480 feet for the same cost per thousand with either horses or tractors. This means that under winter conditions skidding can be more cheaply done with horses for distances up to 480 feet and more cheaply with tractors for all greater distances.

Table 8 also indicates the desirability of giving thorough consideration in the planning of an operation to the possibilities of securing a lower average cost per thousand from stump to landing by the use of a combination of skidding methods.

The combined cost figures given in Table 9 show the relative effect of slope, season, and size of timber upon the combined cost of railroad construction for each of the two methods of skidding. On either slope the spread between costs by the two methods is greater for summer than for winter conditions and greater for three to five log timber than for the smaller size. It will be noted that the costs of handling the 9 to 12 log timber under winter conditions, particularly on the steeper slopes, favor horse work. Were smaller logs being considered, the relatively greater cost for tractor work, due to these conditions, would be brought out even more forcibly.

It is, of course, evident that the several items making up the total costs of skidding by horse and tractor will vary in their relation from year to year for the same operating conditions. For example, the price of hay and oats might go up while that of gasoline and oil might decline. Sufficient change might occur in the cost of certain items to shift the points at which the costs of the two methods are the same. This variation is brought out in additional computations comparing the costs of the two methods after a 7-year interval. The 3-year average cost per effective hour of the horse skidding unit for 1927–1929 is 16 per cent less than that for the period 1920–1922. The cost per effective hour of the tractor-skidding organization, on the other hand, decreased 25 per cent during the same period.

Because of this unequal decrease in the cost per effective hour over the same period of years, the distance at which the cost per housand of the two methods is the same has been reduced an averge of 90 feet for the several different conditions given in Table 8. The greater reduction in the cost per effective hour of the tractorkidding unit is due to improved machines sold at a much lower

price than formerly and to lower consumption per hour of gasoline, oil, and grease, all of which also declined in price. During this period (1927 to 1929) good teams were inclined to increase in value, as did hay and oats. The reduction in the cost per effective hour during the 7-year period for the horse-skidding unit is due almost entirely to a decrease in labor costs.

Tables 8 and 9 illustrate the way in which output data can be applied to operating problems. They could easily be refigured to fit the conditions of any specific problem.

OUTPUT DATA AS A GUIDE TO PROPER UTILIZATION STANDARDS

Logging-output data not only serve as the basis for a more profitable logging operation but also make possible the setting up of effective utilization standards for the individual operation, by means of which it should be possible to leave the forest land in a much better productive state. The most profitable method of operation is often the least destructive and therefore the one in which both the operator and the public should have the greatest interest.

Table 10 indicates the possibility of determining utilization standards. The variation in output and cost from stump to landing or mill is here shown for timber ranging in size from 2 to 22 logs per thousand feet. These figures are based on a horse operation for nearly level areas and steep slopes, at average skidding distances of 200 feet and of 1,800 feet. Thus the influence of slope and distance upon the cost of logging different sizes of material is indicated. Table 10 also brings out more forcibly than do Tables 8 and 9 the difference in output caused by the factor of slope.

TABLE 10.—*Relative output per hour and cost per thousand feet board measure of horse logging large and small timber at different distances and over different slopes*

Size of timber (logs per M)	Sawing		Swamping		Loading		Unloading		Autotruck haul, 1 mile		Total pre-skidding cost
	Output	Cost	Output	Cost	Output	Cost	Ourput	Cost	Output	Cost	
	Ft. b. m.	*Dollars*	*Ft. b. m.*	*Dollars*	*Ft. b. m.*	*Dollars*	*Ft. b. m.*	*Dollars*	*Ft. b. m.*	*Dollars*	*Dollars*
2	1,260	0.86	1,650	0.26	10,950	0.26	18,400	0.08	3,600	0.86	2.32
3	1,280	.85	1.500	.28	10,900	.26	18,600	.07	3,600	.86	2.32
4	1,230	.88	1,350	.31	10,700	.27	18,400	.08	3,500	.88	2.42
5	1,180	.92	1,200	.35	10,200	.28	17,800	.08	3,300	.94	2.57
6	1,130	.96	1,050	.40	9,600	.30	16,800	.08	3,100	1.00	2.74
7	1,060	1.03	930	.46	8,800	.32	15,400	.09	2,860	1.08	2.98
8	1,030	1.06	830	.51	8,000	.36	13,500	.10	2,650	1.16	3.19
9	990	1.10	740	.57	7,250	.39	11,600	.12	2,500	1.24	3.42
10	950	1.15	670	.63	6,600	.43	10,200	.14	2,400	1.29	3.64
11	900	1.21	620	.69	6,000	.48	9,200	.15	2,300	1.34	3.87
12	860	1.27	580	.73	5,550	.51	8,500	.16	2,200	1.40	4.07
13	820	1.33	540	.79	5,200	.55	8,000	.17	2,150	1.44	4.28
14	790	1.38	500	.85	5,000	.57	7,600	.18	2,100	1.47	4.45
15	760	1.43	460	.92	4,800	.59	7,300	.19	2,050	1.51	4.64
16	740	1.47	430	.99	4,650	.61	7,000	.20	2,000	1.54	4.81
17	720	1.51	400	1.06	4,520	.63	6,800	.20	1,950	1.58	4.98
18	700	1.55	380	1.12	4,400	.65	6,700	.21	1,920	1.61	5.14
19	680	1.60	360	1.18	4,350	.66	6,600	.21	1,900	1.63	5.28
20	660	1.65	340	1.25	4,300	.66	6,500	.21	1,880	1.64	5.41
21	640	1.70	320	1.33	4,250	.67	6,500	.21	1,860	1.66	5.57
22	620	1.75	300	1.42	4,200	.68	6,450	.22	1,850	1.67	5.74

TABLE 10.—*Relative output per hour, etc.*—Continued

Size of timber (logs per M)	Horse skidding								Total logging cost			
	Skidding 0–15 per cent slope				Skidding 30–50 per cent slope				0–15 per cent slope		30–50 per cent slope	
	200 feet		1,800 feet		200 feet		1,800 feet					
	Output	Cost	Output	Cost	Output	Cost	Output	Cost	200 feet	1,800 feet	200 feet	1,800 feet
	Ft. b. m.	*Dolls.*	*Ft. b. m.*	*Dolls.*	*Ft. b. m.*	*Dolls.*	*Ft. b. m.*	*Dolls.*	*Dolls.*	*Dolls.*	*Dolls.*	*Dolls.*
2	2, 650	0. 46	425	2. 85	3, 500	0. 35	900	1. 34	2. 78	5. 17	2. 67	3. 66
3	2, 430	. 50	400	3. 02	3, 100	. 39	825	1. 47	2. 82	5. 34	2. 71	3. 79
4	2, 200	. 55	375	3. 23	2, 725	. 44	750	1. 61	2. 97	5. 65	2. 86	4. 04
5	2, 000	. 60	350	3. 46	2, 400	. 50	675	1. 79	3. 17	6. 03	3. 07	4. 36
6	1, 840	. 66	325	3. 72	2, 150	. 56	625	1. 94	3. 40	6. 46	3. 30	4. 68
7	1, 660	. 73	300	4. 03	1, 930	. 63	575	2. 10	3. 71	7. 01	3. 61	5. 08
8	1, 530	. 79	275	4. 40	1, 750	. 69	525	2. 30	3. 98	7. 59	3. 88	5. 49
9	1, 430	. 85	250	4. 84	1, 600	. 76	480	2. 52	4. 27	8. 26	4. 18	5. 94
10	1, 340	. 90	240	5. 04	1, 460	. 83	440	2. 75	4. 54	8. 68	4. 47	6. 39
11	1, 260	. 96	230	5. 26	1, 330	. 91	400	3. 02	4. 83	9. 13	4. 78	6. 89
12	1, 180	1. 03	220	5. 50	1, 220	. 99	375	3. 23	5. 10	9. 57	5. 06	7. 30
13	1, 120	1. 08	210	5. 76	1, 110	1. 09	850	3. 46	5. 36	10. 04	5. 37	7. 74
14	1, 070	1. 13	200	6. 05	1, 020	1. 19	325	3. 72	5. 58	10. 50	5. 64	8. 17
15	1, 020	1. 19	190	6. 37	950	1. 27	300	4. 03	5. 83	11. 01	5. 91	8. 67
16	980	1. 23	180	6. 72	880	1. 38	275	4. 40	6. 04	11. 53	6. 19	9. 21
17	940	1. 29	170	7. 12	820	1. 48	250	4. 84	6. 27	12. 10	6. 46	9. 82
18	900	1. 34	160	7. 56	770	1. 57	240	5. 04	6. 48	12. 71	6. 71	10. 18
19	860	1. 41	150	8. 07	710	1. 70	225	5. 38	6. 69	13. 35	6. 98	10. 66
20	820	1. 48	140	8. 64	650	1. 86	200	6. 05	6. 89	14. 05	7. 27	11. 46
21	790	1. 53	130	9. 31	600	2. 02	190	6. 37	7. 10	14. 88	7. 59	11. 94
22	760	1. 59	130	9. 31	560	2. 16	175	6. 91	7. 33	15. 05	7. 91	12. 65

The ratios of cost per thousand of handling 22-log timber and 2-log timber (taking the latter as unity) for the various phases of the logging operation, are as follows:

Sawing	2, 0
Swamping	5, 5
Loading autotrucks	2, 6
Unloading autotrucks	2. 8
Skidding, 200 feet easy slopes	3, 5
Skidding, 1,800 feet easy slopes	3. 3
Skidding, 200 feet steep slopes	6. 2
Skidding, 1,800 feet steep slopes	5. 2

In these ratios the influence of distance is shown by a comparison of costs in Table 10. Although the cost of skidding 2-log timber on a gentle slope is 6.2 times as great at 1,800 feet as at 200 feet, 22-log timber costs only 5.9 times as much at the greater distance. On a steep slope the big-timber ratio is 3.8 and the small timber ratio only 3.2. This shows that the short haul has less effect in modifying the cost of logging small timber than it has in the case of large timber.

The influence of slope upon the output for large and small timber is shown in Table 10. At the 200-foot distance the case of skidding 2-log timber on the 0 to 15 per cent slope is 1.3 times that for the 30 to 50 per cent slope, and that for the 22-log timber is less, in the ratio of 0.7 to 1. A similar comparison at 1,800 feet indicates that at this distance slope ceases to favor large logs to quite the same degree. The cost for the large timber here is 2.1 times as much on the 0 to 15 per cent slope as on the 30 to 50 per cent slope, whereas that for the 22-log timber is 1.3 times as much on the gentle as on the steeper slopes.

At this point, consideration should be given to the relation of defect to size of timber. This may be very strikingly illustrated. On the 0 to 15 per cent slope with a 200-foot skidding distance, it is evident that timber of 2-log per thousand size can be handled for as low a net cost when 71.3 per cent defective as can perfectly sound timber running 22 logs per thousand under the same conditions. With the same slope at the 1,800-foot distance, the defect in the 2-log timber might be 69.4 per cent. The possible defect would be 84.0 and 80.6 per cent, respectively, for the 200 and 1,800-foot distances on the 30 to 50 per cent slope.

The effect of slope and distance on the cost of the total operation (horse skidding) from stump to landing or mill is also shown in Table 10. Skidding by tractor instead of horses tends to favor large logs more at longer distances and on the lesser slopes.

Table 11 illustrates the effect of different cutting methods upon the logging cost. A typical ponderosa pine stand located in western Montana was selected for the application of these logging-cost data. The original estimate sheets covered an area of 440 acres. The timber was uneven aged, trees in all the 2-inch diameter classes from 10 to 40 inches being represented. The stand per acre averaged 12.17 trees 10 inches and over in diameter, containing 8,993 board feet. The diameter of the average tree in the stand was slightly under 24 inches, and the timber as a whole ran seven and one-half logs to the thousand.

TABLE 11.—*Comparison of horse-logging costs under clean cutting and diameter-limit cutting*[1] *on 440 acres of ponderosa pine in western Montana*

Diameter breast high (inches)	Volume average tree [2]	Trees per acre	Volume per acre	Size of timber [3]	Logging costs under clean cutting: Skidding 200 feet, 0–15 per cent slope: Per M ft. b. m.[4]	Skidding 200 feet, 0–15 per cent slope: Per acre	Skidding 1,800 feet, 30–50 per cent slope: Per M ft. b. m.[4]	Skidding 1,800 feet, 30–50 per cent slope: Per acre
	Bd. ft.	*Number*	*Bd. ft.*	*Logs per M*	*Dollars*	*Dollars*	*Dollars*	*Dollars*
10	60	0.20	12	50.0	13.20	0.16	29.00	0.35
12	94	.84	79	33.0	9.70	.77	19.05	1.50
14	101	.80	81	25.0	8.00	.65	14.35	1.16
16	249	1.45	361	20.0	6.90	2.49	11.45	4.13
18	328	1.18	387	14.0	5.60	2.17	8.15	3.15
20	484	1.61	779	11.0	4.80	3.74	6.90	5.38
22	586	1.32	774	9.0	4.25	3.29	5.95	4.60
24	757	1.64	1,241	7.0	3.70	4.60	5.10	6.33
26	976	1.64	1,601	6.0	3.40	5.44	4.70	7.52
28	1,234	.77	950	4.8	3.10	2.94	4.30	4.08
30	1,565	.39	610	4.0	3.00	1.83	4.05	2.47
32	1,940	.18	349	3.5	2.90	1.01	3.90	1.36
34	2,282	.09	205	3.0	2.85	.58	3.80	.78
36	2,523	.30	757	2.7	2.85	2.16	3.75	2.84
38	3,060	.11	337	2.4	2.80	.94	3.70	1.25
40	3,330	.14	466	2.2	2.80	1.30	3.65	1.70
Total or average	708	12.66	8,989	7.5	3.80	34.07	5.40	48.60
Under diameter limit cutting [1]		8.19	8,069			27.83		38.31
Difference in volume and cost		4.47	920			6.24		10.29
		Per cent	*Per cent*			*Per cent*		*Per cent*
Reduction		35.3	10.2			18.3		21.2

[1] Leaving 10 to 18 inch trees uncut.
[2] Volume of average tree for each diameter class.
[3] Number of logs per thousand for different tree diameters obtained from Figure 4.
[4] Cost for sizes over 22 logs per thousand from Table 10 values curved.

Assuming an average skidding distance of 200 feet and slopes of 0 to 15 per cent, a clean cut of the area, involving the removal of all trees 10 inches and over in diameter, would cost $34.07 per acre. A total volume of 8,989 board feet would be removed. If all 10, 12, 14, 16, and 18 inch trees were left uncut a volume of 8,069 board feet per acre would be removed at a cost of $27.83. This is a reduction of 35.3 per cent in trees logged, 10.2 per cent in volume, and 18.3 per cent in the cost of logging. In other words, by leaving 4.5 trees per acre containing a scale of 920 board feet a saving of $6.24 per acre in the cost of logging is obtained. With the extremes shown in Table 11 and an average skidding distance of 1,800 feet on 30 to 50 per cent slopes, a clean cut of the acre would remove the total volume of 8,989 board feet at a logging cost of $48.60. Cutting to a diameter limit of 20 inches, on the other hand, would leave 4.5 trees to the acre, ranging from 10 to 18 inches in diameter, and provide a cut per acre of 8,069 board feet at a cost of $38.31. This amounts to a 21.2 per cent reduction in logging costs for a 10.2 per cent reduction in volume. It should be stated here that certain logging costs, such as charges for improvements and administration, have not been included in either Table 10 or 11. These costs are not reduced in total by a smaller cut and therefore the charge per thousand feet increases as the volume to be removed decreases. Owing to the small volume involved in Table 11 these charges would have but little effect upon the total logging cost and may be disregarded in the comparisons.

The comparison afforded in Table 11 is presented merely as an indication of the effect of different cutting limits on the cost of logging alone. There are, even here, several factors which must be considered if the most economical operation is to be made possible. The younger or smaller trees to be left in selective logging should vary in size according to the slope of the timbered areas and also the distance which the logs are skidded over that slope. This point is clearly illustrated in Table 11. Sixteen-inch trees skidded a distance of 200 feet on 0 to 15 per cent slopes can be logged for $6.90 per thousand. It will cost $11.45 per thousand to log trees of the same size when skidded a distance of 1,800 feet over 30 to 50 per cent slopes. It may be possible, therefore, to log sound 16-inch trees of good quality that stand within an average skidding distance of 200 feet from the landing, on 0 to 15 per cent slopes, and impractical, from an economic standpoint, to cut the same size and type of tree when it occurs far up on steep slopes a long distance from the landing. The percentage of defect in different-sized logs, which determines whether such logs can be profitably taken or should be left in the woods, also varies with distance and slope.

In determining the proper method of selective cutting to make possible the most economical operation, the value of the products cut from trees of different sizes and the lumber-manufacturing cost, as well as the logging cost, must be considered. Manufacturing costs, like logging costs, increase as the size of the timber decreases. In most species of timber the products cut from small trees are less valuable per thousand feet than those cut from large trees. Detailed information is now available on the production costs and value of the products by tree sizes for a number of the more important timber

species in several of the lumbering regions.[6] With such information available, it is now possible not only to place logging and milling operations on a more profitable basis by selective cutting but to keep large areas of timberlands productive through a sustained-yield system of management.

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[6] Much of the material covering the effect of tree size on production costs is not yet in print. Titles at present available include:

ASHE, W. W.
1926. RELATION OF SIZE OF TREE TO LOGGING COSTS, STUMPAGE VALUES, AND PROFITS. Amer. Lumberman 2683: 73–74.

———
1930. SMALL TREES WASTEFUL TO CUT FOR SAW TIMBER. U. S. Dept. Agr. Leaflet 55, 5 p., illus.

BRADNER, M., and FULLAWAY, S. V., JR.
1927–28. SIZE OF TIMBER, AMOUNT OF DEFECT—IMPORTANT FACTORS IN LUMBERING: AN ANALYSIS OF THEIR EFFECT UPON PRODUCTION COSTS AND VALUES AND THEIR CONSEQUENT INFLUENCE ON PROFITABLE TREE AND LOG UTILIZATION IN THE INLAND EMPIRE. Timberman 29 (2): 38–40, 44–48; (3): 40–46; (4): 62–63; (6): 162–174.

BRUNDAGE, M. R., KRUEGER, M. E., and DUNNING, D.
1933. THE ECONOMIC SIGNIFICANCE OF TREE SIZE IN WESTERN SIERRA LUMBERING. Univ. Calif. Agr. Exper. Sta. Bul. 549, 61 p., illus.

GARVER, R. D.
1927. SMALL SAWMILL UTILIZATION OF SHORTLEAF PINE. Lumber Trade Jour. 92 (9): 40–41.

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1930. SELECTIVE LOGGING OF SOUTHERN PINE. Lumber Trade Jour. 97 (7): 34–35.

———
1930. SELECTIVE LOGGING VERSUS CLEAR CUTTING IN SHORTLEAF PINE. Lumber Trade Jour. 98 (8): 25–26, illus.

GIBBONS, W. H., JOHNSON, H. M., and SPELMAN, H. R.
1929–30. THE EFFECT OF TREE SIZES ON WESTERN YELLOW PINE LUMBER VALUES AND PRODUCTION COSTS. Timberman 30 (12): 44–48, 1929; 31 (1): 241–244; (2): 49–55; (3): 54–56; (4): 49–52; (5): 194–198, 1930.

ZON, R., and GARVER, R. D.
1927. SELECTIVE LOGGING IN THE NORTHERN HARDWOODS OF THE LAKE STATES, WITH SPECIAL REFERENCE TO THE COST OF HANDLING SMALL AND LARGE TREES. 23 p. Oshkosh, Wis.

APPENDIX

RECOMMENDATIONS FOR THE CONDUCT OF LOGGING-OUTPUT STUDIES

GENERAL OBSERVATIONS

Some very definite considerations determine the feasibility and desirability of output studies in any branch of logging. The factors appreciably affecting output must be readily distinguishable and susceptible of classification both for the purpose of study and for application of the results. The particular activity must have a definite effect upon the cost of logging, and the output must not be dependent upon that of some other branch of the operation. If operating conditions are so well standardized that little or no knowledge would be added over that acquired through cost accounts, output studies are unnecessary. Methods and equipment not commonly employed, as well as any abnormal conditions, are naturally excluded.

In order that results may be applicable to specific conditions as found, the data must be collected, segregated, and compiled on the basis of definite natural factors which affect output and can be identified for classification. To insure permanency, all values which are subject to fluctuation, such as rate of pay, effective hours usually worked, and units of measurements for quantity of work done, must as far as possible be reduced to a constant by eliminating variable quantities. Further, to permit general application of logging-output data, only crews of standard size should be studied.

Many factors which influence output in certain branches of logging will be found to vary with the region. Sawing and skidding in the ponderosa pine type of Montana and California may be taken as an illustration of this point. If all factors now used as a basis for measuring output were identical in the two regions there would still be differences in output. These would result from other characteristics such as climate, general broad regional form and height of trees, and a different general class of labor. The combined influence upon output of these and other broad regional characteristics can be accounted for only by separate studies.

DEGREE OF REFINEMENT DESIRED

The extent to which the integral parts of any particular job can profitably be studied depends upon the number of variable factors involved and upon whether or not the conditions under which or the method by which the work is done can be corrected or changed along the lines indicated by the results of the study. When it is evident that output is governed by factors which can not be controlled, it is of no practical value to determine the individual effect of these factors on output.

The methods followed in gathering output data for felling and bucking are pertinent. For this branch of the operation the whole tree has been taken as a basis. Stopwatch determinations might be made of the time required for a saw crew to complete each of the minute parts of the work, such as gathering tools, walking from tree to tree, planning, swamping, barking, undercutting, wedging, oiling, etc. It has been found, however, that such information contains nothing of practical value. It was determined that for the same crew, the relative variation in time needed to perform similar details of the work was greater than the time used in completing similar units of work, each of which was composed of all these details. This is evident in view of the possible variations in the conditions under which the details of the work are carried out. With the whole tree as a basis, a loss in performing one of the details may be compensated for by a gain in others.

Some factors having a great effect on particular phases of the work are either intangible or impossible of classification. No two cuts in sawing are exactly

alike. If the optimum height of log from the ground and position of the sawyer could be determined, the information would have no practical application. The conditions under which the work must be done could not be arranged to meet the specifications.

Time variations caused by the human element further increase the difficulty of obtaining representative figures. One crew will take more time in planning and save time in bucking. Another crew will use more time swamping, wedging, and oiling but conserve time or energy or both in the actual sawing. Very much the same variation was evident in the work of skidding with horses.

Therefore, to attempt the same refinement that has been applied in studies of many other industrial operations is futile in logging work. The elements of human judgment and skill, together with the inability to standardize conditions, enter so largely that even the closest study will not give reliable information. Refinement of methods used in these studies is therefore gauged by the nature of the work and the practical application of the results.

QUANTITY OF DATA REQUIRED

It is impracticable to set a definite standard as to the quantity of data that should be obtained to arrive at a reliable average ouput for any particular unit crew. This depends to a large extent upon how consistent the crews are in their work. Much less information is needed for crews of long-experienced woodsmen than for crews of inexperienced men. Another consideration of importance is the number of factors used as a basis for separating output, and over which the data collected must be distributed.

The number of units of organization which should be included in each set of data must be determined on the basis of possible variation between such units. Obviously the variation will be greatest in work into which the human element enters to the largest extent.

It has been found by experience about how many trees and trips and what scale or time are necessary under each column of the office summary sheet to give the corresponding point on the curve a reasonable degree of accuracy. This statement presupposes that field data have been accurately kept, and that all lost time not properly chargeable against particular units of work has been excluded. Determinations are then made for the average time and scale values of each column in the summary sheet, for work done in one class and under standard conditions according to the method of classification used.

An average of about 15 hours for each diameter class in sawing gives results of sufficient reliability. Thus, if sawing were done in a stand ranging from 12 to 40 inches in diameter, records covering about 15 hours' work on each of the 2-inch diameter breast high classes (15 in all), or a total of 225 hours of effective time, should be obtained. If timber varied from 12 to 20 inches in diameter, 135 hours would give results of equal value. In the former case, assuming the timber to average about 24 inches diameter breast high, scaling approximately 900 feet per tree, and the average output to be 1,100 feet per hour during the 225 hours or 30 days, observation would be made of about 250,000 feet or 275 trees for each curve. If the trees averaged larger than this, obviously the number studied in this time would be less but the total scale greater.

Skidding a distance of 100 feet would require about 15 team hours, provided that all the timber skidded fell into the same log class as, for example, the 3 to 5 or the 9 to 12 log per thousand class; for a 2,000-foot distance, about 150 to 200 hours' observation of one such unit would be necessary to attain a satisfactory degree of accuracy. Since the timber in this region is usually spread over four or five log classes, four or five times as many data, or about 750 to 1,000 team hours, would be required under each slope classification. With an average output of 600 feet per hour, 600 to 700 thousand feet would be the basis for each set of curves.

The more complex the method of transportation, the simpler becomes the gathering of reliable information, since under the complex methods performance is more constant. Thus, in progressing up the line from horse skidding toward railroad transportation, it is found that fewer and fewer data are necessary to establish reliable output.

The speed at which horses travel while skidding on the ground varies with the size of the load, the intangible differences between two skid trails over

apparently similar surfaces, the time of day, the distance of haul, temperature, etc. What horses will do at one distance is not reliable indication of what they will do at another. Some of these variables are eliminated in hauling with drays or trailing in chutes. Notwithstanding, observations are still necessary at frequent intervals to take up the intangible variations. In chute trailing, the rate of travel is fairly constant; distance covered by each item is made quite uniform through relaying, and the time spent in hooking the loads varies less than in skidding, where chaining or dogging the logs is a different problem for each load.

With power-driven equipment, owing to the fact that travel is over roads from which a large majority of the variables have been eliminated and that the logs have been freed from contact with and influence of surface conditions, the rate of travel loaded and empty, size of load, and loading time become relatively constant. For these integral parts of the operation it therefore becomes possible to determine averages which will have common application; those determined for one distance may be applied to any distance.

This method of obtaining averages for component parts of the operation has been used in the studies of autotruck hauling. Observations made at a few different distances have been expanded to cover any desired distance. The same methods have been used in sleigh hauling and chute trailing, with somewhat less accurate results.

From this discussion it becomes obvious that the amount of data needed per unit of distance hauled decreases as the distance increases. The longer the haul, the greater the reduction of variables in the methods commonly employed.

UNITS OF MEASUREMENT

In conducting logging-output and time studies of this character, pages 4 and 5 should be carefully read, and the basic units of measurement therein described should be used unless a better and more logical classification can be devised.

ORGANIZATION AND EQUIPMENT OF STANDARD CREWS

In determining the make-up of crews of standard size only those men are included whose work directly affects the output. For sawing, either contract or day work, the output per hour rests definitely upon the work of two men. Team and teamster and swamper are taken as the unit crew in contract horse skidding. Sometimes one-half the time of chainer or dogger is included. Under day work, swampers are not included, as swamping is usually done in advance and therefore does not interfere with skidding output. In contract work the teamster often assists in swamping. Thus output rests somewhat on the swamper. Brush conditions also are a factor. Output studies have not been made on operations where the team must wait a considerable proportion of the time on the swamper. since this is not considered a representative way of doing the work. In swamping alone, in brush disposal, grading, or any other job performed independently, one man is taken as a unit.

Tractor skidding is based on the work of 10-ton machines with a crew of either two or three men. Some operations necessitate only a driver and a chokerman. In others a chaser is added to the crew. This varies with the nature of the terrain and size of timber. On level open ground with large timber, only two men are needed. Where a bunching team and teamster are used in the woods, they become a part of the unit crew. A team and teamster used on the landing are not considered a part of the crew. These have no influence on output and are generally required only because of the loading method in use.

A standard organization for trailing in chutes is one man and team. A teamster and two or four horses make up the crew in sleigh hauling.

Autotrucks used for hauling logs in this region are commonly of 5-ton or 7½-ton capacity.

The unit for ground donkey skidding includes the entire crew whether the work is on a contract or day basis. This unit has been adopted because, for example, the output of the loading crew is entirely dependent on the one donkey skidding to a certain landing, whereas the loading crew in tractor or horse skidding operations is usually loading from several skidways to which a number of units are skidding.

The landing saw crew is taken as part of the unit crew in donkey skidding but not in tractor work. In the former case the saw crew is an essential part of

the organization, and its output is governed entirely by the donkey. In tractor work, bucking may be done on the landing, or the same saws may be cutting for two tractors or one tractor and several teams.

SEGREGATION OF DATA ACCORDING TO NATURAL FACTORS

The natural factors which have an important bearing on logging output and are used as a basis for the segregation of data are season, slope, surface, forest type, stand per acre, species, height, diameter, and windfall and brush.

FOREST TYPE

Type, by itself, has only a very general value in conveying information relative to logging output or costs. In conjunction with some of the more specific factors, however, it assumes greater importance and tends to give to each of these other factors a clearer definition by narrowing the margin of possible variation within them. A wide variation occurs in the height of western larch in the various types in which it is commonly found. In any specific forest type and region, however, the height variation is much less. It is for this reason that sawing output is divided for different types.

A type classification has other advantages. There are a number of undefinable elements such as soil, brush, windfall, and surface which usually differ with type. Taken individually, each has a rather small and intangible effect on the work; in the aggregate, as expressed in type, they constitute a noticeable factor. This can be readily illustrated.

The surface in a white pine or spruce type is often rough. The soil is soft, filled with roots, and subject to gouging. In a ponderosa pine type, as a rule, larger loads can be pulled over the gentler slopes because the surface is usually firm, smooth, and free from roots. Thus type has been made a factor in skidding.

Where these various elements are found to be the same in two types, the data are either combined or a study is made in but one type. In skidding, the types studied have been grouped as larch-Douglas fir type, white pine, and ponderosa pine type. Each type has been considered separately in compiling sawing data.

TIMBER SPECIES

The species is ordinarily made a basis of segregating output data for sawing, swamping, and brush disposal. Where white pine and white fir or spruce and balsam fir occur in the same type, they have been combined because the output for the two species in each group was practically the same. In other branches of logging the output for all species has been found to be about alike.

HEIGHT OF TIMBER

The effect of height on sawing is not shown specifically on the output graphs. It is accounted for within reasonable limits of variation by making individual curves for each species and each type by regions. An illustration of this point has been given in the discussion of forest type. For a given region, type within that region, and species, the variable of height is confined to a reasonable margin. Without further classification this factor becomes sufficiently specific for all practical purposes. This presupposes, of course, that data have been collected over sufficient exposures and sites to obtain a representative height.

STAND PER ACRE

A distinction in stand per acre has been made only for skidding, swamping, and brush disposal. In the other branches of operations covered by these studies stand has no appreciable effect; on the three mentioned it has but a small intangible influence. The classification of the average stand in which the operation is being conducted has been made on the basis of 5 to 10, 10 to 20, 20 to 40, and over 40,000 feet board measure per acre.

SIZE OF TIMBER

Two classifications are made the basis of recording size of timber. In sawing, the diameter breast high of each tree to the nearest tenth of an inch is recorded, together with the length and gross scale of each log. This gives

the total height utilized and the total scale. The logs per thousand for each diameter class may thus be computed.

For all skidding or moving operations the length and scale of each log are recorded in terms of gross scale per hour of effective time. The number of logs and total gross scale for each trip or other unit of work are kept separate. From these data the average size or logs per thousand for each trip is computed.

The material is divided, according to size, into groups of 1 to 2, 3 to 5, 6 to 8, 9 to 12, 13 to 17, 18 to 25, and 26 or more logs per thousand feet board measure of cut. Output is shown on the basis of these classes. The 6 to 8 logs per thousand class in the output graphs may include logs scaling anywhere from 2 to 20 per thousand but averaging for one trip or load somewhere between 5.6 and 8.5 per thousand. These are the limits of the 6 to 8 log class. These data can be employed in determining the output for any body of timber where the average run of logs is known, through the use of a curve representing such size. Interpolation must be made for sizes which can not be read directly from the curves.

SLOPE

For certain branches of the operation, slope has been classified in different divisions according to its relative effect on the work and to the method of operation employed. In the field work, slopes are read as percentages with the Abney level and recorded by the groups into which they fall.

The slope classifications used in sawing, swamping, and brush disposal are 0 to 30, 30 to 50, and over 50 per cent. It has been found that a finer distinction is unnecessary and tends to complicate the work of the studies. Not until slope exceeds 30 per cent has it any appreciable influence on the output of these phases of logging.

For skidding with horses or tractors by any method in which the source of power itself moves between the stump and the landing, the following divisions of slope have been adopted: 0 to 15, 15 to 30, 30 to 45, and 45 to 60 per cent downhill, and 0 to 15 per cent uphill. The range includes the slopes over which skidding by these methods is commonly carried on. Very little uphill skidding is ever done by any of these methods, except over short distances below railroad spurs or chutes.

The skidding trip from stump to landing is in most cases over a slope which does not vary more than 15 per cent from the maximum to the minimum. Often, however, this 15 per cent range will not coincide with the classification given. In this event, the entire slope is thrown into the slope group which it most resembles and which is most influential in determining the output. A specific example will illustrate this.

Skidding is being done over a total distance of 1,000 feet. Six hundred feet of this is on a 10 per cent slope; the other 400 feet is on a 25 per cent slope. The classification here would ordinarily be the 15 to 30 per cent group. One reason for this is because the weighted average slope is 16 per cent. But another fact is of importance in establishing the slope classification. In actual practice, smaller loads would be skidded over the 25 per cent slope than would be the case if the entire 1,000 feet were on this slope. On the other hand, the loads for the distance over the 10 per cent slope would be larger than if the entire skidding distance was on a 10 per cent slope.

It is, of course, necessary to use judgment in deciding upon slope classification. No skidding trip is made over a slope exactly the same for the entire distance. This is the principal reason for the rather broad classification. Such a basis was essential to its practical application. In cases where there was a considerable difference in the percentage of slope for several portions of the skidding distance, a separate record was kept of the time and amount skidded over each section. At the time of the office compilation it was possible to decide on the most logical slope classification. This would be based on the condition which contributed most to controlling the output. If skidding was done for 300 feet over a 40 per cent slope and then for 500 feet over a 10 per cent slope, two trips might be necessary over the latter distance to handle one trail of logs brought in over the 40 per cent slope. It is readily seen that the 10 per cent slope would largely be the controlling factor. Classification would be made accordingly.

For sleigh hauling, chute trailing, and draying, slopes of 0 to 5, 5 to 10, and 10 to 15 per cent with distance for each are recorded. Nearly all sleigh haul-

ing is done over slopes from 0 to 15 per cent. A 3 to 5 per cent slope is most nearly ideal. Greater slopes, within moderation, do not have any effect on output. More sandmen would of course be required. By far the greatest factor in sleigh hauling is the kind of winter weather. This is a rather indefinable factor which can be treated in only a very general manner at best.

Autotrucks are normally used for hauling only on slopes of between 5 per cent uphill and 10 per cent downhill. Records were made in the field showing separately the total distance traveled with load over uphill slopes of 0 to 5 per cent and over downhill slopes of 0 to 5 and 5 to 10 per cent. Trucks equipped with 4-wheel brakes are sometimes operated on downhill slopes to a maximum of 25 per cent. No such slope conditions were encountered in these studies, however. No distinction is made in the difference in slope or distance of the return empty which is nearly always made over the same route. Output figures are segregated by types of road, as dirt, plank, and pole roads.

The influences of slope conditions on ground skidding with a donkey are many and varied as compared with horse skidding in the same type of country. With steam power the logs are skidded up and down hill, and at every imaginable angle along the sides or diagonally across the slopes. Little sidehill skidding is necessary with horses or tractors, owing to the comparatively small cost of constructing landings and of moving equipment. Most of the timber is moved almost straight downhill; very little is taken uphill. Even skidding along the sidehill with these two methods does not present the difficulties from logs rolling or hanging up behind stumps that are usual in ground yarding with donkeys.

In donkey skidding, it has been assumed that the difference in output due to skidding up, down, or along the side of a hill is not sufficient to justify segregation for slopes under 30 per cent. The classification so far used, though it has not been experimented with to any extent, is: Uphill 30 per cent to downhill 30 per cent; uphill 30 to 50 per cent; uphill 50 to 70 per cent; downhill 30 to 50 per cent.

WINDFALL AND BRUSH

Brush and windfall are reported as lacking or as light, medium, or heavy, in comparison with the average quantities for the type in this region. The condition as to brush and windfall is used as a basis of showing separate output for sawing, swamping, brush disposal, and contract horse skidding. In other methods of skidding, swamping is either done in advance or not at all and has little influence on output results. The condition is, however, recorded and shown on all graphs as a matter of general information.

SURFACE

Surface conditions are not differentiated in relation to output, because the difference caused by the greatest variation encountered in these studies was not appreciable. Classification of surface is in general terms, such as smooth or rough, and is used simply to indicate the nature of the area. In sawing, particularly, a rough surface in light stands decreases output and loss from breakage is greater. Logs must frequently be cut shorter than would be necessary had the break not occurred.

SEASON

Weather conditions have a variable and extremely important influence on the output of nearly all branches of logging work. No operator can afford to ignore them. On two chances, similar in every respect, one operator will be forced to cease operations on account of weather conditions whereas the other will not only be able to continue but will turn the conditions to his advantage.

In a logging chance on which half the timber is on level ground and half on slopes ranging from 30 to 50 per cent, weather conditions should receive thorough consideration when the operation is planned. Logging the steep slopes during the summer months and the flat ground in winter will make the work not only continuous but cheaper.

Provision should be made to take advantage of seasonal changes, in so far as they can be anticipated, and to regulate seasonal output accordingly. Little consideration can be given to minor variations in weather; adjustment must be based on broad classifications on the basis of average summer and average winter conditions. No attempt is made to show production as affected by

changes within the seasons in spite of the great influence these exert over short periods. Instead, an average is obtained by carrying the study over a period sufficient to include a fair representation of such conditions within the region.

In collecting the data it was found necessary to draw a rather arbitrary line between summer and winter conditions. Winter conditions were assumed to exist whenever the logs could be skidded without gouging through the frozen ground or snow to the soft earth beneath, when timber becomes frozen, or when the snow is deep enough to interfere with sawing. A daily record was kept in camp of the depth of snow, of whether the ground was frozen or soft, and of the temperature.

FIELD RECORDS AND EQUIPMENT

For gathering data in the field, two sets of records are used. The first set, for the actual field work, is in notebook form. Figures 49 and 50 show samples of such forms, which are the usual type of notebook sheet.

DATE ________ TYPE ________________ OPERATION ______________

Species	D.B.H (in.)	Time of start	Time on tree (min.)	LOG		Tree scale (10 feet b.m.)	Top diameter (in.)	Slope (per cent)	Brush	Surface
				Length (feet)	Gross scale (10 feet b.m.)					
White Pine	26	8.20	50	16	30	97	9	20	H	R
				16	28					
				16	21					
				14	14					
				16	4					
		9.10	5	Lost time - resting						
White Fir	32	9.15	75	16	38	158	6	10	m	S
				16	33					
				10	19					
				6	11 - Break					
				16	24					
				16	16					
				14	10					
				16	6					
				12	1					
		10.30								

FIGURE 49.—Record form for sawing data

In the use of these forms, the beginning of any unit of work, lost time, or quitting time is recorded to the nearest even minute under "Time of start." The difference between the time of starting one thing and of starting the next is recorded in minutes, not hours and minutes, in the next column, opposite the time of its start. When the day's work is finished, the record indicates what was done every minute of the day from the time the tools were picked up until they were put away. Following the "Trip time" or "Tree time," there is either a record of the unit of work accomplished or an explanation of the disposition made of that time.

In sawing, the length and gross scale for every cut are given. This applies whether the piece is a merchantable log, a cull, or a break which is trimmed. If no cut is made where the break occurs, whether in the top or elsewhere, the piece is scaled as though it would make a merchantable log. In this manner the composite effect of breakage, for the conditions existing on any particular chance, is taken into consideration. This record of breakage and top diameter makes possible the construction of a volume table based on actual utilization. The percentage of breakage may also be determined. Should it be desired to base the volume table on a specific top diameter, a record can be made of the length of the top piece, to this diameter, left in the woods.

In the use of the skidding form the actual distance traveled along the slope while under load (not the horizontal distance), if 100 feet or more, is recorded for each trip to the nearest even 100 feet; anything less than 50 feet is recorded as 25 feet. Long distances, where appreciable error is apt to occur in pacing, are chained and marked up on stumps or stakes for future reference.

The second set of records is made up of camp summary sheets, on which are recorded the total or average daily records. These sheets are also used for the collection of data on other jobs, particularly swamping, as these data

DATE ____________

TYPE ____________ BRUSH ______ WINDFALL ______ OPERATION ___________

Time of start	Trip time	Distance skidded (feet)	Slope (per cent)	LOG: Length (feet)	LOG: Gross scale (10 feet b.m.)	Trip scale (10 feet b.m.)	Logs (number)	Size of tree (logs per M)
8.00	20	300	25	16 16 14	18 16 4	38	3	6-8
8 20	32	500	25	12 18 16 16	3 5 8 3	19	4	17-25
8.52	23		Lost	time -	repairing	rigging		
9.15								

FIGURE 50.—Record form for skidding and hauling data

may be collected in conjunction with the regular output work. Figure 51 indicates the nature of this sheet.

By changing headings or adding others for number of men on loading or unloading crew, road monkeys, or sprinkler and rutter crew and teams, this form may also be used to record any desired information with autotruck or sleigh haul or may be adapted to any study.

A daily record is kept also of the distance to work, method of travel, conditions of road or trail, etc. From these data the number of effective hours for any job can be closely estimated.

Date	Effective time (hours)	Total camp scale (10 feet b.m.)	Unit crews (number)	Swampers (number)	Chainmen (number)	Tail-down men (number)	Weather conditions

FIGURE 51.—Camp summary form for skidding and draying operations

The equipment necessary to carry on the field studies is as follows: Accurate timepiece, scale rule—Scribner decimal C, steel tape (100 feet and menders), diameter tape (20 feet), Abney level (per cent), notebook, and timber crayon, The diameter tape is used to determine diameters of logs which can not be scaled directly with the rule.

PERSONAL REQUIREMENTS

It is essential that men detailed to output studies have a genuine interest in them and that they place reliance on the general principles upon which such studies are based. Without this viewpoint, it is doubtful whether anyone conducting observations over any length of time will continue to maintain the necessary degree of accuracy after the novelty of the work wears off. The men must also, as in any work of this nature, have the proper conception of the value of accuracy and detail.

A majority of workmen, especially woodsmen, object to stop-watch methods. Tact and diplomacy is necessary in association with both laborers and supervisory staff. The observer must refrain from statements that are liable to affect

the normalcy of output. Experience in several specific cases has shown that men have either speeded up or slowed down as the result of unconsidered statements, thus making the data collected worthless and misleading.

The observer should make no remarks, criticisms, or suggestions to the workmen in regard to their methods, output, scale, wages, or piece rate. He should collect information on what they do, as they do it. The camp foremen should be given nothing which will lead to a comparison of the work of two crews. Also, no new ideas on methods of conducting the specific operation need be offered to the foreman. There is ordinarily a good deal more to be learned from this individual than can be told him. The old-time practical logger in charge of an operation has his head full of practical, everyday, common-sense ideas. He knows how to get his work done without too many preliminaries. He likes rule-of-thumb and short-cut methods. The observer should not try to convert him but should study his methods of accomplishing his ends and learn to apply as far as possible, what is good in them. There is no man more generous in his impulses and more willing to help anyone who is ambitious and sincere in his efforts to learn the practical side of logging than this old, experienced logging foreman.

Work performed by any individual crew or unit of organization should not be divulged to any one connected with the operation. If the men doing the work realize that this is the policy, there will ordinarily be no objection to the methods followed in these studies and men will work at a normal pace.

Ordinarily, someone with considerable experience in work of this kind should spend a day or two with men starting out for the first time on this work or changing to a new job with which they have had no experience. In that length of time it is possible to explain on the ground, during the actual process of collecting the data, the instructions needed by the observer. Periodic visits to each man are made every month or six weeks. Doubtful points, which frequently come up during the course of the work, are taken up and a general inspection and check of the work accomplished are made.

COMPILATION OF DATA

The working up of the field notes into final form consists, briefly, of the following steps.

(1) Determining the logs-per-thousand group of each load or trip.

(2) Transferring to large tabulation sheets the time and scale under their proper diameter breast high columns for sawing, or distance for skidding or hauling, and then finding the total of this time and scale.

(3) Distributing the total lost time by prorating it against the total working time to which it is chargeable.

(4) Finding the gross output per hour for each diameter class or distance and evening-off the results by drawing a curve through these values plotted on cross-section paper.

Where logs are skidded or hauled with horses in lengths as actually bucked, the number of logs per thousand in the lengths as handled is the element of size that governs output. Calculation is, therefore, made on the basis of the actual number of pieces it will take to make a thousand feet, without reference to the run of the timber in standard 16-foot logs. In tractor or donkey skidding, timber is handled in double-length logs, or often in tree lengths. Bucking into short logs takes place on the landing or in the mill. Size of material in this case is determined and expressed in terms of the number of standard 16-foot logs per thousand feet irrespective of lengths into which these are bucked. This distinction is made because in tractor or donkey skidding the logs can be bucked into any lengths without materially influencing the output. In horse logging this would not be true.

A number of unit crews may be working together, making the output of any one somewhat dependent upon the others, as where several teams are skidding to the same landing or several auto trucks are hauling between the same loading and dumping grounds. The work of such unit crews should be summarized together. On work where each unit is entirely independent of the output of others and in which the period of time over which observations were carried on is not approximately the same, results of each must be summarized and the output of each first determined separately. A flat average of all is then found. To summarize the time and scale for all units together would be to weigh the output of each on the basis of the amount of data obtained for

each crew. If the crew with the greatest output was observed over the longest period of time, values would be abnormally high and not representative of the average crew.

When the data are transferred from the field notes to the summary sheets, a separate summary sheet is provided for each set of conditions, each sheet bearing the heading of but one type, season, slope, log group, and so on.

Lost time, concerning all work done under conditions which go into the same curve or set of curves, is added together and not separated by logs per thousand for transportation or by species for sawing.

Table 12 has been prepared to show that in ordinary stands of timber it is unnecessary to consider diameter classes separately in computing output from the graphs. However, in stands having two distinct size-classes of timber it is necessary to give separate consideration to each of the groups.

TABLE 12.—*The computation of logs per thousand for sawing*[1]

Diameter breast high[2] (inches)	Trees	Logs per tree	Total logs	Gross volume per tree	Total volume	Gross output per hour[3]	Sawing time
	Number	*Number*	*Number*	*Ft. b. m.*	*Ft. b. m.*	*Ft. b. m.*	*Hours*
14	10	4	40	210	2, 100	600	3. 5
16	15	5	75	340	5, 100	740	6. 9
18	20	5	100	410	8, 200	850	9. 6
20	30	6	180	580	17, 400	945	18. 4
22	10	6	60	690	6, 900	1, 030	6. 7
24	10	7	70	970	9, 700	1, 100	8. 8
26	5	7	35	1, 170	5, 850	1, 160	5. 0
Total	100		560		55, 250		58. 9

[1] The totals in columns 4 and 6 indicate the average logs per thousand to be approximately 10. Reference to fig. 1 will show that white pine timber 20 inches in diameter will yield 10 logs per thousand. The total of column 6 divided by that of column 8 gives 938 feet as the weighted average output per hour of all diameter classes. Fig. 1 shows the output per hour for timber 20 inches in diameter or 10 logs per thousand to be about 945 feet. This indicates that, in ordinary stands of timber, it is unnecessary to consider diameter classes separately. However, in stands, for example, having a large percentage of the volume in 14 and 16 inch trees and the balance in trees from 36 to 40 inches, it is necessary to give separate consideration to each of these groups.

[2] White pine stand on best site.

[3] Output taken from fig. 1.

LABOR AND SUPPLY COST TABLES

In figuring the cost per thousand in any of the phases of the logging operation covered by the output graphs the wages of the different classes of woods workers employed or the cost per effective hour or day of the unit crew or organization used in doing such jobs are necessary information. For those using the output data in this bulletin who do not have at hand such information, Tables 13 to 20, giving wage or unit costs, have been prepared. These tables give the wages per hour, day, or month as the case may be of the several classes of woods workers, as well as the cost per effective hour or day of the unit crew employed in doing a specific piece of work. The tables are based on "Inland Empire" wages and supply costs for periods of one to three years from 1927 to 1929, inclusive. In case the labor and supply costs given in the tables do not apply at the time it is desired to use the output data, similar tables can be prepared on the basis of the wages and cost of supplies prevailing at a particular time.

Table 13.—*Sawing and hauling crew costs per effective day, based on five different estimates of freight and handling charges on provisions and supplies*[1]

Freight and handling charges per pound	Cost of saw crew[2]			Cost of team and teamster[3]		
	1929 average	2-year average	3-year average	1929 average	2-year average	3-year average
No cost[4]	$8.40	$8.40	$8.40	$6.50	$6.60	$6.60
0.5 cent	8.70	8.70	8.70	7.30	7.40	7.40
1 cent	9.00	9.00	9.00	8.00	8.10	8.20
1.5 cents	9.20	9.20	9.20	8.70	8.80	9.00
2 cents	9.50	9.50	9.50	9.50	9.70	9.70

[1] This table is based on "Inland Empire" wages and team expenses for periods of 1 to 3 years, and on months of 24 effective days.

[2] Includes cost of files, oil, and a proportionate charge for time of filer, but does not include depreciation on saws and other tools. In 1929 at least 90 per cent of all the sawing in the "Inland Empire" was contract work at a cost of $1 to $1.45 per thousand for short logs. Contract felling and topping for tractor skidding costs between 50 and 90 cents per thousand. To the contract price must pe added the cost of saws and other tools, oil and saw filing, and depreciation on the tools, which run about as follows per thousand: Saw and other tools, 9 cents; files and oil, 2 cents; saw filing, 8 cents; and depreciation on tools, 6 cents.

[3] Includes barn care, medicine, shoes, nails, veterinary services, board and loss on board, and a normal amount for idle teams that averages about 12 to 15 per cent of the total; depreciation on horses and harness not included; 40 pounds of oats and 60 pounds of hay per day per team.

[4] Except such costs as are incurred on account of time of barn boss, bull cook, and clerk; applicable to camps so located that there are no other freight or handling charges; seldom used.

Table 14.—*Cost of logger-type, 10-ton tractor and driver per effective day*[1]

Item	Cost
Driver	$6.50
Gasoline	9.00
Oil and grease	2.00
Maintenance	7.50
Total	25.00

[1] The above is a weighted average based on 2,400 effective days in western Montana. Depreciation is not included in the above table. The life of a logging tractor should be figured as 4 years logging and a residual value of 20 per cent. This gives a straight depreciation of 20 per cent per year and amounts to about $5 per effective day. The above costs are for ponderosa pine skidding. Drivers' wages are for effective days only and 10 hours' time. Wages, repairing, and all parts are charged to maintenance. Gasoline, oil, and other supplies were brought in by logging train or autotruck. The above costs are figured on gasoline at a price of 18 to 22 cents per gallon, oil at 70 to 75 cents per gallon, and grease at 16 to 19 cents per pound. Effective days per year 180 to 235 with an average of 200. Days laid up for repairing or repairs average 20 to 30 per year.

Table 15.—*General wages of woods labor*[1]

Position	Range—1929 average	Position	Range—1929 average
Locomotive engineer	$5.00–$6.00	Cant-hook men	$3.40–$4.00
Locomotive brakeman	3.80– 4.50	Swampers	3.20– 3.60
Locomotive firemen	3.60– 4.20	Common labor	3.20– 3.40
Jammer engineer	5.25– 6.00	Tractor engineer[2]	6.00– 7.00
Jammer hooker	3.40– 4.00	Chokerman	3.80– 4.50
Top loader	3.80– 4.50	Teamster	3.60– 4.00

[1] Rate per 8-hour day. [2] Includes overtime repairing or greasing.

TABLE 16.—*General wages of administrative men* [1]

Position	1929 average wage	Position	1929 average wage	Position	1929 average wage
Logging superintendent	$400	Blacksmith	$135	Night watch	$95
Logging foreman	195	Machinist	180	Supply man	200
Straw boss	135	Barn boss	105	Scaler	145
Handy man	80	Bull cook	95	Clerk	150

[1] Rate per month, including cost of board; the 2-year and 3-year averages are practically the same as those for 1929.

TABLE 17.—*Unit cost of organization for horse skidding*

Unit	Cost per 8-hour day	Cost per hour
Team depreciation and interest	$0.55	
Team and teamster	7.40	
One-half time of chainer or dogger	1.70	
Total	9.65	$1.21

TABLE 18.—*Unit cost of organization for tractor skidding*

Unit	Cost per 8-hour day	Cost per hour
Tractor depreciation and interest	$5.15	
Gasoline, oil, and grease	11.00	
Maintenance	7.50	
Driver	6.50	
Total	30.15	
Tractor unit	30.15	
Choker man	4.15	
Total	34.30	$4.29
Tractor unit	30.15	
Choker man	4.15	
Chaser	4.15	
Landing team and teamster	7.40	
Total	45.85	5.73
Tractor unit	30.15	
Choker man	4.15	
Swamper	3.40	
Total	37.70	4.71
Tractor unit	30.15	
Choker man	4.15	
Swamper	3.40	
Bunch team and teamster	7.40	
Total	45.10	5.64

Table 19.—*Unit cost of organization for loading autotrucks or sleighs*

Unit	Cost per 8-hour day	Cost per hour
Top loader	$4.15	
Two hookers	7.40	
Team and teamsters	7.40	
Tail-down man	3.70	
Total	22.65	$2.83

Table 20.—*Unit cost of organization for autotruck haul*

Unit	Cost per 8-hour day	Cost per hour
Driver, wages and board	$6.20	
Depreciation	5.00	
Interest	.74	
Insurance	2.00	
Repairs	6.00	
License	.20	
Gasoline at 10 cents per mile [1]	2.40	
Tires at 8 cents per mile	1.92	
Oil and grease at 1 cent per mile	.24	
Total	24.70	$3.09

[1] 12 trips per day, 2 miles per trip.

GLOSSARY OF LOGGING TERMS USED [7]

Bunch team.—A team used to bunch logs in one place for skidding or loading.

Chain.—A short length of chain used to fasten around a log or bunch of logs for skidding with horses.

Chainer.—One who places the chain around the log or bunch of logs in skidding.

Choker.—A short piece of cable or wire rope used in the form of a noose so that the log may be hooked to the tractor or donkey for skidding.

Choker man or choker setter.—The member of a skidding crew who fastens the choker on the log.

Chaser.—A member of a tractor skidding crew who accompanies the tractor with its load of logs from the woods to the landing to assist along the way and to unhook the chokers at the landing and see that they are returned to the woods with the tractor.

Crosshaul.—A method of loading and decking logs by use of a chain or cable set across the load through a snatch block. The end of the loading chain or cable may be equipped with either swamp hook or crotch chain. The power is generally supplied by horses or small tractor.

Deck up, to.—To pile logs upon a skidway.

Dog.—A short heavy piece of steel bent and pointed at one end with an eye or ring at the other. Two dogs connected by a short length of chain are used to hook logs together end to end to form a trail of logs for horse skidding.

Dogger.—One who connects the logs together end to end by means of dogs.

Dray.—A single sled, or two wooden sled runners with a crownpiece, slipped under one end of a bunch of logs for dragging.

Hang up, to.—To fell a tree so that it catches against another instead of falling to the ground.

Gin pole.—A pole secured by guy ropes, to the top of which tackle for loading logs is fastened.

Gyppo. Gyppo logging.—Small-scale contract logging; for example, when a large company contracts with a gyppo and his crew to log outlying sections that with the standard crew and equipment would be handled less economically.

[7] The definitions are given with special reference to their meaning as used in the "Inland Empire" region.

Horse jammer.—A single pole or arrangement of poles equipped with loading tackle and used with horse power to load logs on sleighs, autotrucks, or cars. An end horse jammer loads from a position at the end of the sleigh, autotruck, or car.

Jig team or make-up team.—A team of horses used in making up a trail of logs in a chute at a skidway, landing, or point of entrance.

Plank road.—A road constructed by placing parallel three or more poles of medium size lengthwise along the road and covering crosswise with 3 to 6 inch planking. Additional planks are sometimes laid lengthwise on top of these for the tread. The road is used to haul logs with autotrucks.

Pole road.—A road constructed of poles for hauling logs with autotrucks. Four poles (two on each side) are laid lengthwise upon mudsills or cribbing. The outside poles are hewed to a flat surface to form the tread or track.

Road monkey.—A woods laborer who keeps a logging road in proper condition for operation.

Rutter.—A form of plow for cutting ruts in a sleigh road for the runners of the sleds to run in.

Rutter crew.—The driver of the team that draws the rutter, and a helper who assists in seeing that the ruts are properly cut in depth and line.

Sustained yield.—Cutting a forest at a rate not exceeding the production capacity of the area, thus giving a continuous and regular output of forest products

Swamper.—A woods laborer who cuts out the skidding trail and trims the limbs from the log preparatory to skidding.

Tail down, to.—To roll logs on a skidway to a point on the skids where they can be easily reached by the chuting, fluming, or loading crew.

Trail of logs.—Two or more logs dogged together end to end, for horse skidding or lying end to end to make up a load for trailing in a chute.

Whistle punk or signal man.—One who transmits orders from the foreman of the yarding crew to the engineer of the yarding engine.

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